CAREC ROAD CRASH INVESTIGATION MANUAL

MARCH 2025

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CAREC
Central Asia Regional Economic Cooperation Program

ADB

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In this publication, “$” refers to United States dollars.

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Abbreviations

ADB	Asian Development Bank
BCR	benefit–cost ratio
CAREC	Central Asia Regional Economic Cooperation (Program)
FSI	fatal and serious injuries
GIS	geographic information system
iRAP	International Road Assessment Programme
NPV	net present value
SPI	safety performance indicators

1 Introduction

This manual aims to improve procedures for collecting, investigating, and analyzing crash data in the Central Asia Regional Economic Cooperation (CAREC) countries.[1] It is intended for use by agencies in charge of collecting road crash data, such as police departments, the health sector, as well as all national government and nongovernment stakeholders who utilize these data. The guidance provided in this manual aims to enhance these agencies' data collection systems and support informed decision-making to improve road safety, and offers strategic recommendations based on globally recognized best practices.

The manual focuses mainly on crashes with fatal and serious injuries (FSI), as they undermine the economic and social development of a country. According to estimates from the European Bank for Reconstruction and Development, they cost between 3% and 5% of countries' gross domestic product.

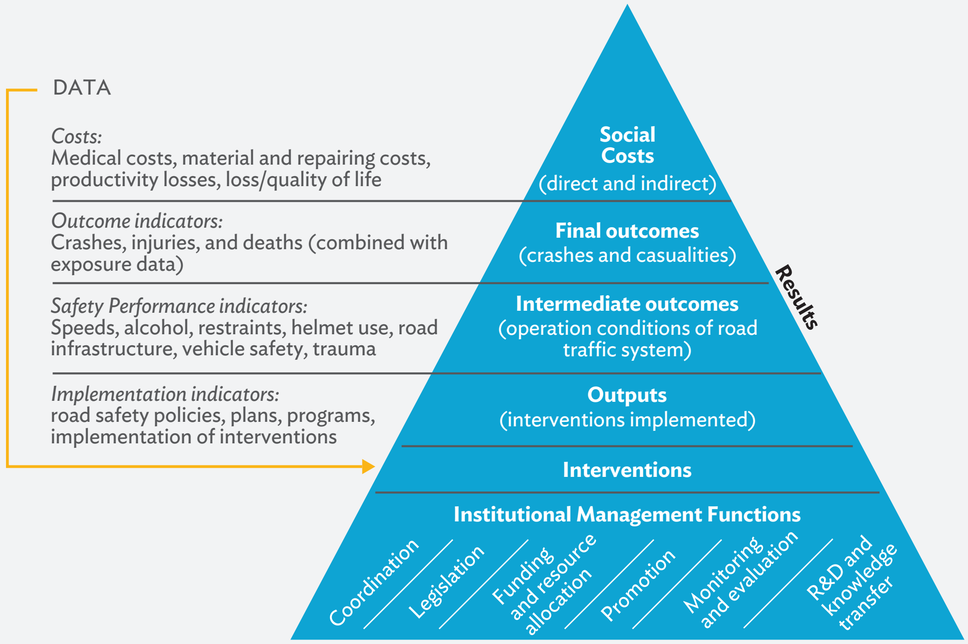
1.1 Background

The quest for improved road safety, which aims to reduce the unacceptable social and economic losses resulting from road trauma, relies heavily on a country's capacity in managing road safety issues. As shown in Figure 1, this framework is given by the correlation of three different elements:

- The foundation of the system consists of ***institutional management functions***, i.e., the arrangements and capacities for coordination, legislation, financing and resource allocation, promotion, monitoring and evaluation, research and innovation, and knowledge development and transfer in the field of road safety. Institutional management should be results-focused and promote the adoption of the "Safe System" approach and principles.
- The second element of the road safety management system concerns ***interventions*** that implement evidence-based approaches to prevent or reduce exposure to the risk of death and serious injury, and to reduce the severity of crashes should they occur.
- The third element of the system is related to the ***results***, expressed as final outcomes (long-term goals), intermediate outcomes (midterm improvements toward the outcome), and outputs (indicators linked to the outcomes, such as data on interventions implemented to achieve these outcomes).

[1] Afghanistan, Azerbaijan, the People's Republic of China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan. https://www.carecprogram.org/ . ADB placed its regular assistance to Afghanistan on hold effective 15 August 2021.

Figure 1: Road Safety Management System



R&D = research and development.

Sources: Bliss and Breen. *Building on the Frameworks of Land Transport Safety Authority*, 2000; Wegman, 2001; Koornstra et al., 2002; Bliss, 2004.

Countries with the safest road networks share many common features in their management of road safety, particularly in the effective functioning of all three system elements.

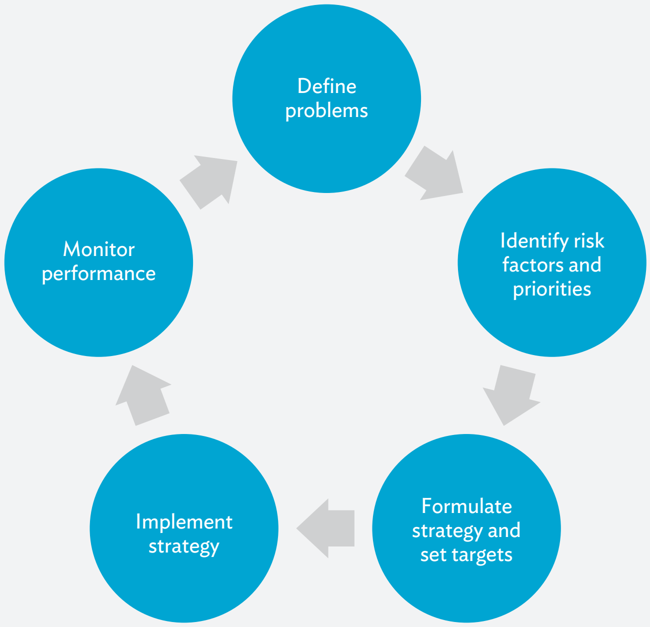
The results are the focus of the entire system of road safety management and the final product. They are measured and monitored through **road safety data**. Specifically, the intermediate and final outcomes are the number of road crashes and crash casualties, and the associated costs. To be fully understood, these outcomes must be combined with **risk exposure data** and data describing the safety performance of the traffic system (**safety performance indicators**).

Finally, it is critical to collect and evaluate data on interventions (output data) to understand the status and effectiveness of actions and tasks undertaken.

Outcome and output data are at the core of any evidence-based decision-making process. An evidence-based approach to road safety management follows the iterative process illustrated in Figure 2. It begins with defining the problem, and proceeds with identifying and prioritizing risk factors, setting targets, defining actions and strategies to achieve the targets, implementing the strategy actions, and monitoring and evaluating their impact. All these elements require reliable data.

The whole process should be developed in keeping with the **Safe System principles**, which recognize the vulnerability of humans and the fact that they tend to make mistakes; the road traffic system should be designed to prevent these mistakes from resulting in fatalities or serious injuries. The Safe System approach also acknowledges that road safety is a shared responsibility of those who plan, design, manage, and use the road traffic system, and those who provide post-crash care.

Figure 2: Road Safety Decision Cycle



Source: World Health Organization. 2010. *Data Systems: Road Safety Manual for Decision-makers and Practitioners*.

To achieve better road safety results, decision-makers and road safety practitioners in CAREC countries need to strengthen their road safety data frameworks, and establish solid and sustainable mechanisms for data collection, management, analysis, and monitoring.

Improving the road safety data framework in a country is a key step in the development of a National Road Safety Observatory and a resource for improving the activities and outputs of the **Asia-Pacific Road Safety Observatory**. These observatories are crucial for enhancing the quality of road safety statistics and databases, promoting more appropriate solutions for data systems, and facilitating comparisons between countries.

1.2 Scope and Structure of the Manual

This manual is focused primarily on providing guidelines based on international best practices to standardize systems for **collecting, managing, and analyzing road crash and road safety data** within each CAREC country and at the regional level.

The manual focuses on road crash data and, more specifically, on FSI crashes, which form the backbone of road safety management systems. The manual also covers other aspects of road safety needed to complete the road safety picture of a country or region and create a solid basis for informing decision-making processes.

The manual is structured into three main sections (Figure 3).

The first section deals with **data collection**. It proposes a classification of collisions based on a minimum set of variables to be collected when an FSI crash occurs. These variables, which must be collected following standard procedures and definitions, allow for the identification of the systemic failures that led to the road crash.

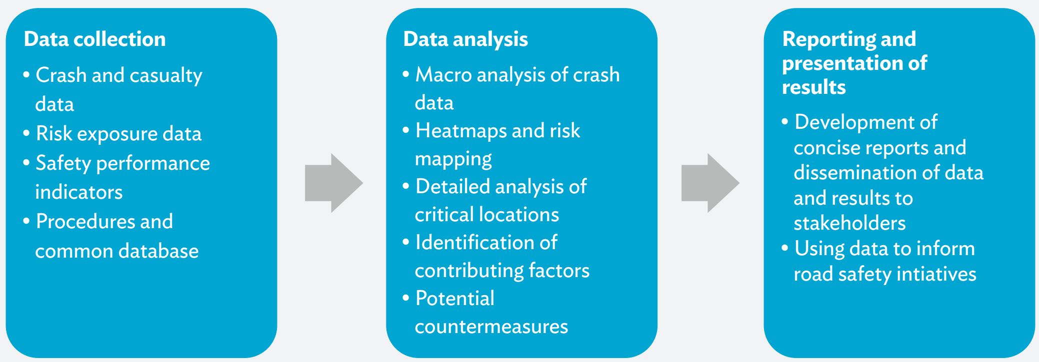
This section also includes procedures for collecting risk exposure data and safety performance indicators (SPI).

Finally, the most common challenges in data collection systems and possible solutions to mitigate them are identified, as well as guidelines for data collection in compliance with health and safety protocols.

The second section deals with **data analysis**. Here, the most important analyses and investigations to be conducted on crash casualties and other road safety data are outlined. The analyses follow a logical structure that starts with a macro analysis of trends and statistics at the country and/or regional level and moves to identifying specific high-risk locations. The analysis culminates with the identification of FSI crash contributing factors and potential countermeasures to mitigate them.

Finally, the third section sets out summary guidelines on how to **present and disseminate data and results** effectively, as well as how to use data to inform road safety initiatives.

Figure 3: Structure of the Crash Investigation Manual



Source: FRED Engineering.

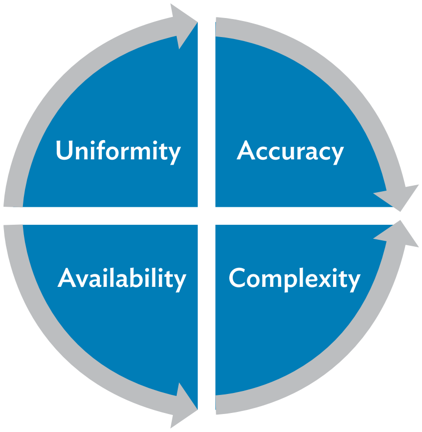
2 Data Collection

To understand a country's road safety problems, set targets, establish road safety policies, and evaluate their success, it is essential to collect and collate accurate data related to road safety. These data form the basis of the entire road safety management system. All road safety policies and interventions must be informed by accurate and comprehensive data to deliver economically and socially effective results.

The main data to be collected in the field are FSI crash and casualty data (so-called "outcome data"), which provide an overview of the extent of a country's road safety problems and the efficiency of its road safety management systems. To have a greater impact, however, these data should be supplemented with information on the safety performance of the road traffic system (by referring to risk exposure data and SPI) and on interventions to improve road safety.

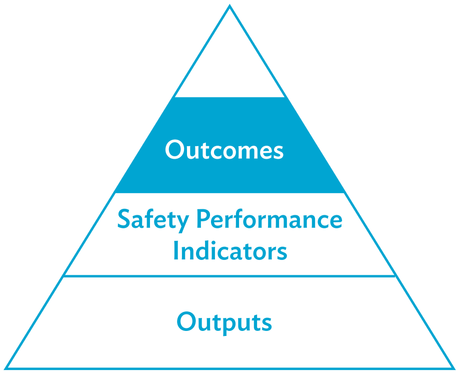
All data collected should fulfill the following requirements:

- **Accuracy.** More accurate data allow for a better understanding of the road traffic system and the safety problems that need to be addressed.
- **Complexity.** The data must be comprehensive and include all system characteristics to allow a more complete view of the current situation and more targeted and potentially effective planning of interventions.
- **Availability.** All data needed to understand the road safety picture must be available and accessible to all relevant stakeholders.
- **Uniformity.** Standard definitions should be applied in data collection and analysis to standardize data interpretation and enable comparisons at the national and regional levels.



Data, depending on their type and nature, are collected or used by various entities, including traffic police, hospitals and other health sector agencies, road administrations, national statistics offices, etc. Although each agency typically has its own internal database, it is essential that all data are also collected and validated within a **central road safety database** hosted and managed by one of the national agencies and accessible by any other agency playing a role in road safety.

2.1 Crash and Casualty Data



Crash and casualty data are the pivotal data on which road safety management systems rely. They must be collected accurately and comprehensively, following standardized procedures that can be adapted to each specific context and reality.

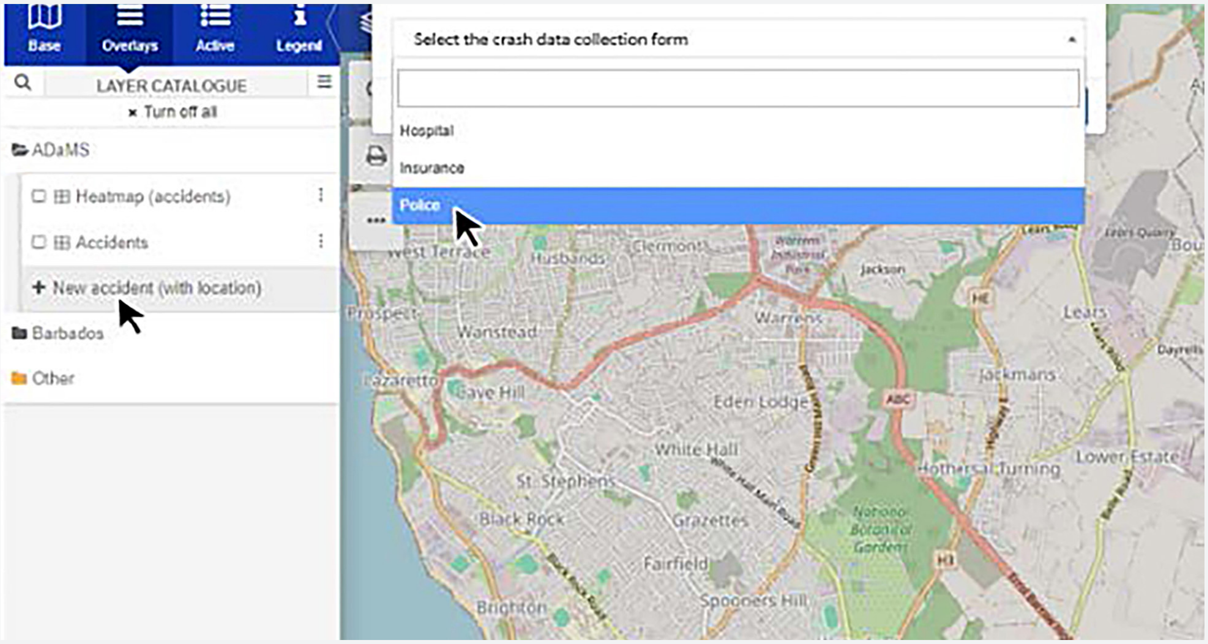
FSI crash data are typically collected by several actors, including traffic police, hospitals and the health sector, and, to some extent, insurance companies, which use their own data collection systems and databases. The collected data are then used by statistics offices and other national stakeholders to produce and release road safety statistics, and by government and road agencies to inform decision-making (e.g., prepare road safety strategies, select and implement road safety interventions, etc.).

However, a unique and comprehensive road crash registration system must be established or strengthened in each CAREC country. Ideally, all agencies within a country should collect crash data using a common web-based information system (Figure 4). Such a system should allow for standardized data collection, storage, and analysis. The exchange of information among agencies should be protected by an appropriate computer security mechanism that ensures confidentiality, integrity, authentication, and nonrepudiation of data.

The use of a common information system for data collection, analysis, and management makes it possible to

- reduce underreporting of FSI crashes (for instance, combining information collected by multiple agencies reduces the percentage of unreported crashes and results in a more comprehensive database);
- increase data accuracy (e.g., hospitals can have access to the system to update in real time the status of hospitalized victims within 30 days after the FSI crash);
- produce comprehensive and standardized analyses at the local, national, and regional level; and
- streamline data management, analysis, and use processes for all stakeholders and decision-makers (all relevant stakeholders will have access to the database, albeit with different levels of permission).

Figure 4: Example of a Common Information System Used by Police, Hospitals, and Insurance Companies to Collect Data—Each User Has Access Only to the Respective Module



Source: FRED Engineering.

2.1.1 Common Challenges to Crash Data Collection and Investigation

Underreporting of crashes and inaccuracy of collected data are generally due to several challenges common to almost all countries. These challenges are summarized in Table 1, along with recommendations to mitigate them.

Table 1: Common Challenges to Crash Data Collection and Investigation

No.	Challenge	Recommendation	Responsibility
1	Capturing all major crashes is essential for evidence-based decision-making in road safety. In several countries, the absence of effective notification and registration process is a source of underreporting.	Actions to ensure capturing all major crashes can range from set up of a unique notification number to use of information systems for collection, recording, and transmission of road crash data.	Agencies in charge of crash data collection (police, insurance companies, health sector) Central road safety agency
2	The use of paper-based data collection forms, open text fields, or poor data collection mechanisms can undermine data standardization and cause loss of information in analysis and statistics.	Maximize the use of electronic devices for data collection. Use preset and standardized forms that minimize the occurrence of errors and typos.	Agencies in charge of crash data collection (police, insurance companies, health sector)

continued on next page

Table 1 continued

No.	Challenge	Recommendation	Responsibility
3	The absence of automated and well-established police–hospital communication mechanisms may result in inaccurate information on the outcome of crashes. In fact, the police diagnosis at the time of the crash may not be exhaustive (especially if there are multiple injuries). It is necessary to conduct clinical examinations and follow-up with victims up to 30 days after the event to determine the actual severity of the injuries.	Establish systematic and automated police–hospital communication mechanisms and procedures to enable appropriate follow-up of hospitalized victims in the 30 days following the crash (or until the victim is discharged from the health facility). The common information system referred to in the next point plays a key role in this regard. When the victim is discharged from hospital or dies (or in any case after 30 days), the responsible health services must be able to update the crash victim's form and send it to the national crash database, where the information on the victim's condition will be integrated with the data collected by the police on the crash in question. This procedure should be facilitated by the common information system, which should enable cross-checking and combining crash information collected by the police, hospitals, and other sources.	Hospitals and the health sector Police Central road safety agency
4	The absence of a national common information system for collecting, storing, managing, and analyzing data increases the rate of unreported crashes, compromises the accuracy and completeness of data that should inform road safety decision-making, and complicates the management and accessibility of data by all relevant agencies and stakeholders.	When not yet in use, it is recommended that a common information system is established for data collection, storage, and analysis, managed by a central national road safety agency.	Government Central road safety agency Agencies in charge of crash data collection (police, insurance companies, health sector)
5	The absence of standard definitions at the national and regional level does not allow for comprehensive comparisons of road safety data and monitoring of countries' progress in road safety.	Standardize road safety definitions and variables first at the national level and then at the CAREC region level. Crash variables and definitions should be clear, unambiguous, and follow international best practice. The variables in section 2.1.3 and their respective definitions can be used as a reference to harmonize data collection, management, and analysis across countries.	Government Central road safety agency Regional road safety observatories and intergovernmental stakeholders from CAREC countries Agencies in charge of crash data collection (police, insurance companies, health sector)

continued on next page

Table 1 continued

No.	Challenge	Recommendation	Responsibility
6	Injuries to pedestrians, cyclists, and nonmotorized users are much less likely to be reported.	Vulnerable road users are disproportionately involved in road crashes and should be a key target in road safety policies. It is important that officers who collect crash data and crash investigators are well informed about this and trained to analyze crashes involving these users.	Agencies in charge of crash data collection (police, insurance companies, health sector)

CAREC = Central Asia Regional Economic Cooperation.

Source: FRED Engineering.

When it comes to CAREC countries, some common challenges (Box 1) can be identified concerning road crash data collection and investigation.

Box 1: Crash Data Collection and Investigation Procedures in CAREC Countries

- Is there a unique emergency number for crash notification?

  Only Georgia (112) and Pakistan (911) use a unique and simple crash notification number.

- Are there internationally recognized definitions for crash casualties?

  Only Kazakhstan and Uzbekistan use a definition of crash fatality that complies with the internationally recommended definition (person who died because of a road crash at the crash scene, or as a result of it, within 30 days). None of the CAREC countries use a definition of serious injury that conforms to international standards (most countries have no definition of serious injury).

- Are all crashes with victims attended by police and medical services?

  In general, in all countries, police must attend all traffic crashes, and generally claim to be able to intervene in most of them (with an efficiency level varying by region). Some countries report a shortage of medical personnel and emergency vehicles, resulting in longer transport times for victims to medical facilities, especially in remote rural areas. In addition, in some cases, procedures are not uniform across the country.

- Do the crash forms used by police forces allow for concise and reliable analyses?

  Across the CAREC region, the variables collected by the traffic police do not fully align with international good practice standards such as CADaS. The extent of these gaps varies depending on the country.

- Is there a common information system for the storage and use of crash data?

  CAREC countries do not have a common crash database, which increases the likelihood of underreporting and may affect the accuracy and completeness of the analyses. Some countries, such as Kazakhstan, have open portals to visualize and analyze crash data in the country. Other countries, such as Azerbaijan, Georgia, the Kyrgyz Republic, and Uzbekistan, are in the process of approving or designing a common crash database.

CADaS = Common Accident Data Set, CAREC = Central Asia Regional Economic Cooperation.

Source: Consultations with stakeholders from various CAREC countries (2023–2024). FRED Engineering.

2.1.2 Injury Severity Definitions

According to international best practices, data on fatal crashes and severe injuries must be prioritized, while data on crashes involving only vehicle damage can be neglected.[2]

Some of the CAREC countries lack clear definitions, coherent with the international standards, on injury severity which can lead to incorrect analyses.

To indicate to what extent a person (driver, passenger, pedestrian, etc.) has been injured as a result of a road crash, various injury classification systems can be used such as Injury Severity Score, Abbreviated Injury Scale, etc. Since these systems are scarcely available in most CAREC countries, a simpler definition based on patients' hospitalization hours is suggested. However, it would be appropriate in the future to adopt a definition based on the abovementioned classification systems.

According to these concepts, a revision of the current national standards is recommended to comply with the following definitions (Table 2).

Box 2: Definition of Road Crash Fatality in Uzbekistan

Out of nine countries assessed in the CAREC region, Uzbekistan is the only one besides Kazakhstan defining a crash fatality as "an event involving one or more persons who died as a result of a road crash at the crash scene or as a result of it within 30 days."

This definition is set of the decree No.303, approved on 15 November 2011 by the Cabinet of Ministers of the Republic of Uzbekistan.

Source: Consultations with stakeholders (2023–2024). FRED Engineering.

Table 2: Definitions of Crash Fatalities and Injuries

Category	Internationally Agreed Definition
Fatalities	People who die immediately or within 30 days as a result of a road traffic crash
Serious injuries	People with a Maximum Abbreviated Injury Scale (MAIS) equal or greater than three. If MAIS is not available: people hospitalized for more than 24 hours.
Minor injuries	People with a MAIS lower than three If MAIS is not available: people given first aid at scene or treated in a medical facility as outpatient or discharged from hospital within 24 hours.

Source: Mobility and Transport Department. European Commission.

2.1.3 Collision Classification System

When conducting a crash investigation, it has been a historical practice for police to focus on the culpability of drivers and securing evidence. The main objective of the police is generally to ensure security and thus to prosecute offenders when necessary. However, the Safe System approach has reversed this paradigm by recognizing that humans tend to make mistakes, and that the road transport system must be designed to prevent

[2] H. Martensen et al. 2021. *Guidelines for Conducting Road Safety Data Reviews.* World Bank.

these mistakes from leading to serious or fatal injuries. It is therefore necessary to embrace a broader approach that aims to identify the systemic failures that led to the crash and does not focus solely on seeking the road user's faults. This requires collecting information on all system components to determine what specific elements contributed to the occurrence of the crash. An example case study based on the crash manual produced by the Global Road Safety Partnership[3] is provided in Box 3.

While the police must continue collecting information for prosecution purposes, there is the need to ensure that road crash data are also collected for statistical and decision-making purposes.

The severity of crash injuries is not always evident at the crash scene. The condition of victims may change as days go by. It is therefore important that persons involved in the crash are followed up within a month of the crash to assess the extent of their injuries. In this regard, it is necessary that hospitals where the victims were admitted inform the police of the progress of their condition, so that more reliable analyses can be conducted. The use of a single national system for recording and storing crash casualty data (as explained in section 2.4 of this manual) is essential to ensure an effective link between the traffic police and medical facilities.

Box 3: Example of Single Crash Investigation Following a Safe System Approach

Event:

An 18-year-old male driver became distracted with his cell phone, swerved out of his lane, and an oncoming truck hit him head-on. The driver was traveling at 85 kilometers per hour (km/h) (5 km/h above the posted limit). The road was a single two-way carriageway, with one lane in each direction. The crash occurred at night (around 9 p.m.), in poor visibility conditions, and one of the headlights on the young driver's car was malfunctioning. The driver was not protected by any restraint device and was tired after the day's work.

A bystander walking on a protected footpath at the roadside witnessed the crash and called the first- aid services, which arrived on the scene after 26 minutes and found the young driver seriously injured.

Investigation:

Safe speeds

The 80 km/h speed limit is 10 km/h greater than the speed recommended by the Safe System approach for this type of road. In fact, the survivable speed in a head-on crash is 70 km/h. At higher impact speeds, the likelihood of being fatally injured increases exponentially.

In addition, the driver was traveling 5 km/h over the legal limit (thus, 15 km/h above the survivable impact speed).

Safe roads and roadsides

The road is a single two-way carriageway, with one lane in each direction. Opposite directions are separated by a continuous center line. The absence of a central reservation calls for travel speeds below 70 km/h. It would be beneficial to adjust the speed limit or enhance the median treatment. Furthermore, the fact that the driver travels above the speed limit requires an assessment of the need to install traffic-calming measures appropriate to the use and context of the road.

Street lighting is not present, but the dynamics of the crash and the presence of pedestrians on the roadside (the bystander who witnessed the crash) may make it necessary.

continued on next page

3 Global Road Safety Partnership. 2021. *Crash Investigation and Reporting Guide*. International Federation of Red Cross and Red Crescent Societies.

Box 3 *continued*

There is a protected footpath, but it must be assessed whether the barrier offers sufficient protection in the event of impact at the posted speed, or whether it is necessary to reduce speeds or increase the segregation of pedestrians.

Safe vehicles

While basic vehicle characteristics are recorded at the crash scene (for each vehicle involved in the crash), a deeper technical inspection would be useful to verify that there were no mechanical or other failures prior to the crash (e.g., tire pressure and condition, efficiency of the vehicle's braking and steering systems, vehicle crashworthiness, presence of functioning safety equipment such as head and side protection airbags and 3+ point seat belts for all occupants, etc.).

Any possible factors that contributed to the crash (including the failure of one of the vehicle's headlights) should be recorded.

Safe road use

Details about the drivers of the car and truck are recorded, and a blood (or breath) sample is taken and analyzed to verify if alcohol or drug levels are above legal limits.

The driver's attitudes at the time of the crash can be recorded as well (e.g., cellphone use, non-use of seat belt, speeding, etc.).

Ideally, the investigation should extend to the driver's workplace to assess if he actually worked so many consecutive hours and possibly suggest a revision of company policy on overwork plus driving home. The same should be checked for the truck driver, verifying that he or she also complies with safety policies (e.g., on driver fatigue or consecutive hours of driving).

Post-crash response

The ambulance staff must include advanced paramedics who rapidly assist and stabilize the crash victim, before transporting him to a nearby hospital for trauma care. Details about the victim should be collected, including the type of injuries sustained and the overall injury severity according to a standard classification system (e.g., MAIS3+).

To increase the victim's chance of survival, the total prehospital post-crash response time should not exceed 60 minutes (the so-called "golden hour"). The fact that the crash site was reached in 26 minutes casts doubt on the possibility of completing the prehospital response within 1 hour. Therefore, it is necessary to check the accessibility of the area from the nearest emergency medical centers and take actions to improve it.

At the time the victim is discharged from the hospital, or in any case by the 30th day after the crash, hospitals must update data on the severity of the victim's injuries in a national database so that complete and correct crash and casualty analyses can be made.

Source: Global Road Safety Partnership.

For statistical and decision-making purposes, four categories of variables are recommended for collection when a collision occurs:

- Crashes
- Roads
- Traffic units (vehicles and pedestrians)
- Persons

Box 4: Road Crash Variables in Pakistan

The National Highway & Motorway Police (NHMP) in Pakistan collects a number of variables on road crashes, including information related to the crash environment, the vehicles, and the persons involved.

NHMP currently collects 31 variables related to road crashes. Most of them are coherent with the minimum set of variables recommended at international level.

Despite this, NHMP still does not record the precise coordinates of road crashes (as well as most of the other CAREC countries).

CAREC = Central Asia Regional Economic Cooperation.
Source: NHMP.

Standard definitions should be used for each variable at the national level and, to the extent possible, regional level to allow comparison between data collected by different agencies and between different countries, and to facilitate analysis.

The variables listed in Tables 3–6 show the minimum set of data needed by road engineers to understand the dynamics of the crash and its contributing factors. Their use is recommended in all CAREC countries.

Crash-Related Variables

These variables include basic information about the crash, including the location, general dynamics, environmental conditions, and whether the crash resulted in injury or death.

The variables related to the crash are described in Table 3. The table also contains guidance on how to collect variables following standard definitions and which entities should collect them. The following icons are used in the table:

Table 3: Variables Related to Crash

Variable	Standard Definition	Data Format	Collected by		
			[police icon]	[medical icon]	[checklist icon]
Crash ID	Unique crash identifier	10-digit code. The first two letters are the country Alpha-2 code (e.g., TM for Turkmenistan). The next eight digits refer to the date in the format YYYYMMDD. The last four digits are an increasing number starting from 0000. As far as possible, this ID should be automatically filled in by an information system and used for cross-referencing data.	•	•	•

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Table 3 continued

Variable	Standard Definition	Data Format	Collected by		
Date	Date (day, month, and year) of the crash	An eight-digit number consisting of the day, month, and year (DD/MM/YYYY) in which the crash occurred. If any part of the crash date is not known, the entire date can be filled by entering 99 for the day and month, and 9999 for the year.	•	•	•
Time	Time at which the crash occurred	A four-digit number based on the format: hh:mm. The time of the crash should be given even if the minute is not known. The recorded time refers to the local time at the crash scene and the 24-hour clock format (00:00–23:59) is used to represent it.	•	•	•
Region	Region or major territorial subdivision where the crash occurred	Indicate the official name of the region or territorial subdivision without adding any other information or details, and without using acronyms or abbreviations.	•		•
City/Location	City/municipality or location subdivision where the crash occurred	Indicate the official name of the city/municipality or location without adding any other information or details, and without using acronyms or abbreviations.	•		•
GPS coordinates	The latitude and longitude of the geographic location of the road crash[a]	WGS84 can be used as reference system. If WGS84 is used, a seven-digit number is filled in both for the latitude and longitude (+ or – sign following which three digits and four decimal places are entered).	•		•
Crash or impact type	Crash type in terms of vehicles and persons involved, type of crash, vehicle/pedestrian maneuver performed by the vehicle(s) shortly before the crash occurred, hit-and-run crash	See **Table A1.1** in Appendix 1 Multiple types may be attributed “to a single road crash. In such cases (e.g., multi-vehicle collision and hit-and-run pedestrian), several variables must be selected.	•		
Weather conditions	Atmospheric conditions at the crash location at the time of the crash	Select an option among: **01 Dry/clear** **02 Rain** **03 Snow** **04 Fog/mist/smoke** **05 Sleet/hail** **06 Severe winds** **99 Other or unknown**	•		

continued on next page

Table 3 continued

Variable	Standard Definition	Data Format	Collected by		
			Police	Hospital	Insurance
Light conditions	The level of light at the crash location at the time of the crash	Select an option among the following: **01 Daylight** **02 Darkness and streetlights lit** **03 Darkness and streetlights unlit** **04 Darkness and absence of streetlights** **99 Unknown** Both natural and artificial lighting are considered.	•		
Crash severity	Generic severity of the crash	Select an option among: **01 Non-injury** **02 Minor injury** **03 Serious injury** **04 Fatal** **99 Unknown** If more than one person was involved in the crash, this variable represents the condition of the person who sustained the greatest injury (e.g., if out of three people, two came out unharmed and one with serious injuries, "serious injury" should be recorded).	•		
Property damage other than vehicles	Factor that takes into account whether there was property damage outside the vehicles directly involved in the crash	Select an option among the following: **01 Yes** **02 No** **99 Unknown**			•

Police Hospital Insurance

Note:
[a] The recorded GPS coordinates should be related to the point of impact, not the final position of the vehicle.
Source: Mobility and Transport Department. European Commission.

Road-Related Variables

These variables include information about the road and the environment in which the crash occurred. Road variables are described in Table 4. The table also contains guidance on how to collect variables, following standard definitions and which entities should collect them.

Table 4: Variables Related to Road

Variable	Standard Definition	Data Format	Collected by		
Road	Name of the road according to the official nomenclature	Enter the official ID and name of the road.	•		•
Functional class – 1st road	The functional class of the road where the crash occurred	Select an option among the following: **01 Primary arterial** **02 Secondary arterial** **03 Collector** **04 Local** **05 Other** **99 Unknown** These options are customizable depending on the country classification system. For crashes at intersections, the road that has priority is designated as the first road. Priority is governed by appropriate signs, traffic lights, traffic police, or other intersection control systems.	•		
Functional class – 2nd road (if intersection)	The functional class of the second road at the site where the crash occurred	Select an option among the following: **01 Primary arterial** **02 Secondary arterial** **03 Collector** **04 Local** **05 Other** **06 Not applicable** **99 Unknown** These options are customizable depending on the country classification system. This variable applies **only to crashes that occur at intersections**. The non-priority road is designated as the second road (priority is governed by appropriate signage, traffic lights, or other types of intersection regulation system).	•		

continued on next page

Table 4 continued

Variable	Standard Definition	Data Format	Collected by		
Carriageway type	Indicates the direction of travel and the number of lanes of the carriageway	Select an option among the following: **01 One-way road** **02 Two-way undivided road** **03 Dual carriageway (central reservation is present)** **99 Unknown** For crashes at intersections, the variable is filled in for the main road only.	•		
Number of lanes	The total number of traffic lanes constituting the carriageway (transit and auxiliary lanes are not counted)	The number of traffic lanes (considering all directions) is filled in. Use 99 for unknown number of lanes. For crashes at intersections, the variable is filled in for the main road only.	•		
Surface conditions and status	The predominant conditions of the road surface at the crash site	Select an option among the following: **01 Dry** **02 Snow/Frost/Ice/Slush** **03 Wet/Damp** **04 Flood** **05 Other** **99 Unknown**	•		
Road type	Road alignment and whether there are any civil engineering structures (tunnels or bridges) at the site of the crash	Select an option among the following: **01 Straight, flat, and without civil engineering structures** **02 Curve** **03 Tunnel** **04 Bridge** **05 High gradient for the operating conditions** **06 Other** **99 Unknown**	•		
Speed limit	The speed limit located at the scene of the road crash	Speed limits should be recorded at 10 kilometers per hour (km/h) intervals. Enter a two- or three-digit code (e.g., 80, 90, 100, etc.). Use 99 for unknown posted speed or no speed limit. The unit of measurement of the variable km/h.	•		
Type of intersection	For any road crash that occurs at an intersection, the type of intersection/ interchange should be indicated	See **Table A1.2** in Appendix 1.	•		•

continued on next page

Table 4 continued

Variable	Standard Definition	Data Format	Collected by		
			Police	Hospital	Insurance
Type of intersection control	If the crash occurred at a junction, indicate how road user flows and rights-of-way were managed at the crash time	See **Table A1.3** in Appendix 1.	•		
Work zone	Work zone close to the location of road crash	Select an option among the following: **01 Yes** **02 No** **99 Unknown** This includes construction or maintenance work zones. A crash is considered related to a work zone when vehicles, due to the presence of the work zone, perform maneuvers such as slowing down, stopping, or changing direction.	•		
Urban area	Indicates whether the road crash occurred within an urban area	Select an option among the following: **01 Yes (inside urban)** **02 No (outside urban)** **99 Unknown**	•		

Police Hospital Insurance

Source: Mobility and Transport Department. European Commission.

Traffic Unit-Related Variables

These variables include information about the traffic unit(s) involved in the road crash. Traffic units may refer to vehicles or pedestrians. The main purpose of including pedestrians among traffic units is to simplify the analysis of crashes and casualties by road user type.

Insurance companies may be required to collect a broader range of information related to the vehicle for their own purposes. Table 5 lists only variables useful for crash investigation and road safety analysis. The table also provides guidance on how to collect variables following standard definitions and which entities should collect them.

The set of variables listed in Table 5 should be provided for each traffic unit separately.

Table 5: Variables Related to Traffic Unit

Variable	Standard Definition	Data Format	Collected by		
Traffic Unit ID	It is possible to cross-reference the traffic unit record with crash and person records through the Traffic Unit Identification Number. A unique link will be created with the Crash ID and the Person ID	A two-digit number starting from 00 assigned to each traffic unit involved in the crash. Vehicles and pedestrians are considered traffic units.	•		
Traffic Unit type	Type of traffic unit involved in the crash	See **Table A1.4** in Appendix 1.	•		
Trailer	Indicates whether a trailer or semi-trailer was pulled by the vehicle when the crash occurred	Select an option among the following: **01 Yes** **02 No** **03 Not applicable** **99 Unknown** In case of a pedestrian or a nonmotorized two-wheeled vehicle, the variable cannot be applied.	•		
Vehicle registration year	Indicates the registration year of the vehicle(s) involved in the crash	A number consisting of four digits is filled in using the following format: YYYY. Use 9999 for unknown year. In case of a pedestrian or a nonmotorized two-wheeled vehicle, the variable cannot be applied.	•		
Vehicle registration country	Indicates the country of registration of the vehicle(s) involved in the crash.	The country code is filled in as indicated here: https://www.iban.com/country-codes The variable cannot be applied if the person involved in the crash is a pedestrian or a cyclist.	•		
Traffic Unit maneuver	Specifies the maneuver related to each traffic unit involved in the crash	See **Table A1.5** in Appendix 1.	•		
Insurance	Indicates whether the vehicle was properly insured at the time of the crash	Select an option among the following: **01 Yes** **02 No** **03 Not applicable** **99 Unknown** The variable cannot be applied if the person involved in the crash is a pedestrian or a cyclist.	•		•

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Table 5 continued

Variable	Standard Definition	Data Format	Collected by: Police	Collected by: Hospital	Collected by: Insurance
Technical inspection	Indicates whether the vehicle had a valid certificate of passing roadworthiness inspection at the time of the crash	Select an option among the following: **01 Yes** **02 No** **03 Not applicable** **99 Unknown** The variable cannot be applied if the person involved in the crash is a pedestrian or a cyclist.	•		•
Overloading	Indicates whether the vehicle was overloaded in terms of number of passengers, load weight, or oversized load	Select an option among the following: **01 Yes** **02 No** **03 Not applicable** **99 Unknown** The variable cannot be applied if the person involved in the crash is a pedestrian or a cyclist.	•		•
Hit and Run	Indicates whether at the crash scene the vehicle was registered by the police or the vehicle fled after the crash	Select an option among the following: **01 Yes** **02 No** **03 Not applicable** **99 Unknown** The variable cannot be applied if the person involved in the crash is a pedestrian or a cyclist.	•		

Police Hospital Insurance

Source: Mobility and Transport Department. European Commission.

Person-Related Variables

These variables include information about the road users involved in the crash. For each person, the set of variables is provided in Table 6. Personal information such as the person's first and last name is used for cross-checking data and is not published or used in national statistics.

Insurance companies may be required to collect a broader range of person-related information for their own purposes. Table 6 lists only variables useful for crash investigation and road safety analysis. The table also provides guidance on how to collect variables following standard definitions and which entities should collect them.

Table 6: Variables Related to Person

Variable	Standard Definition	Data Format	Collected by		
Name and surname	Name and surname of each person involved in the crash	Name and surname are filled in by writing.	•	•	
Person ID	The person identification number allows for information related to traffic unit to be cross-referenced with information related to the crash and persons involved	A two-digit number starting from 00 assigned to each person involved in the crash	•	•	
Date of birth	Date of birth of each person involved in the crash	An eight-digit number consisting of day, month, and year (DD/MM/YYYY) is filled in.	•	•	
Gender	Gender of each person involved in the crash	Select an option among the following: **01 Male** **02 Female** **99 Unknown**	•	•	
Nationality	Nationality of each person involved in the crash	The country code is filled in as indicated here: https://www.iban.com/country-codes	•		
Road user type	Type of road user involved in the crash	Select an option among the following: **01 Driver/rider** **02 Passenger** **03 Pedestrian** **99 Unknown**	•		
Seating position in/on vehicle	Indicates the seating position in/on the vehicle of each person at the time of the crash	Select an option among: **01 Driver/rider** **02 Front seat** **03 Rear seat (including two-wheeler passengers)** **04 Standing in vehicle** **05 Not applicable or elsewhere** **99 Unknown** Not applicable for pedestrians.	•		
Driving license issue date	Indicates the date the driving license has been issued	A six-digit number consisting of the month and year (MM/YYYY). This variable applies only to drivers, otherwise "Not applicable" option should be selected. Indicates the date of issue (month and year) of the driver's license of the person(s) involved in the road crash.	•		•

continued on next page

Table 6 continued

Variable	Standard Definition	Data Format	Collected by		
Driving license validity	Indicates the validity of the driver's license	Select an option among the following: **01 Valid and appropriate for the vehicle driven** **02 Expired/Suspended** **03 Not applicable** **99 Unknown** This variable applies only to drivers, for other road users, the "Not applicable" option should be used.	•		•
Date of admission	The date of the person's admission to the health service (typically an emergency center)	An eight-digit number consisting of day, month, and year (DD/MM/YYYY) is filled in.	•	•	
Time of admission	The time of day the person was admitted to the health service (typically an emergency center)	A four-digit number based on the format: hh:mm is filled in.		•	
Date of exit	The date when the person has been discharged by the health service (because he/she died or recovered)	An eight-digit number consisting of day, month, and year (DD/MM/YYYY) is filled in.		•	
Alcohol use	Indicates whether the driver or rider tested positive for alcohol	Select an option among the following: **01 Positive (alcohol level above national legal limit)** **02 Negative (alcohol level below national legal limit)** **03 Not applicable (person, passenger or pedestrian not subjected to alcohol test)** **99 Unknown** This variable is applicable only if the type of road user is a driver or a rider.	•		
Safety equipment use	The use of safety equipment by drivers/passenger at the time of the crash	Select an option among the following: **01 Seat belt worn** **02 Seat belt not worn** **03 Seat belt not installed in vehicle** **04 Child safety seat properly installed and used** **05 Child safety seat not properly installed/used (child on board)** **06 Crash helmet worn** **07 Crash helmet not worn** **08 Not applicable** **99 Unknown** Not applicable for pedestrians.	•		

continued on next page

Table 6 continued

Variable	Standard Definition	Data Format	Collected by		
			Police	Hospital	Insurance
Distracted by electronic device	Indicates possible driver/rider distraction due to use of electronic devicee	Select an option among the following: **01 Yes** **02 No** **03 Not applicable** **99 Unknown**	•		
Injury severity	Indicate the final diagnosis assigned by the health service personnel to the person(s) involved in the crash	Select an option among the following: **01 Not injured** **02 Minor injury** **03 Serious injury** **04 Death** **99 Unknown injury** Typically, the final diagnosis is assigned when the person is discharged from the health service or at the 30th day after the crash.		•	
Type of injury	Indicate the type of injury sustained by the person involved in the crash	The type of injury is generally determined based on hospital records and may vary from country to country. **Table A1.6** in Appendix 1 shows a reference that can be used at regional level.		•	

Police Hospital Insurance

Source: Mobility and Transport Department. European Commission.

2.1.4 Crash Data Collection Forms

Crash data collection forms must be standardized at the national level and, as far as possible, at the regional level. All entities must collect the respective variables as defined in section 2.1.3 or in a manner allowing for association of variables. The use of heterogeneous variables or definitions undermines the harmonization of crash investigation procedures and data analyses and, consequently, the effectiveness of road safety interventions.

A paper form or an electronic form may be used for data collection. In both cases, the information should be validated and transferred to a central database as quickly as possible (a maximum of 24 hours after the crash occurrence is recommended).

Validation of the police and insurance forms must take place at the hands of a crash inspector who checks that there are no inconsistencies in the data recorded and that all crash variables are filled out correctly. Once validated, the form is sent to a national central database. Further validation should be done by the agency that hosts and manages the central database.

Recommended data collection forms for police and hospitals are given in Appendix 1. These forms are built based on the tables presented in section 2.1.3.

2.1.5 Collision Diagrams

The collection of road crash data variables is an essential element for identifying high-risk crash locations on a road or road network, trends over time, and aggregate statistics on crashes or existing risk factors.

Collision diagrams, on the other hand, have the primary function of showing the crash patterns on a specific location. They consist of a planimetric representation of crashes recorded at a site over a given period of time.

Individual collision diagrams should be drawn by the data collection specialist (usually a police officer) at the crash site or later in the office, using standardized and uniform symbology (an example of an individual collision diagram is given in Appendix 1). The symbology used in the Highway Safety Manual can be used as a reference (Figure 5).[4] An example of collision diagram including key distance measures and roadside furniture is provided in Figure 6.

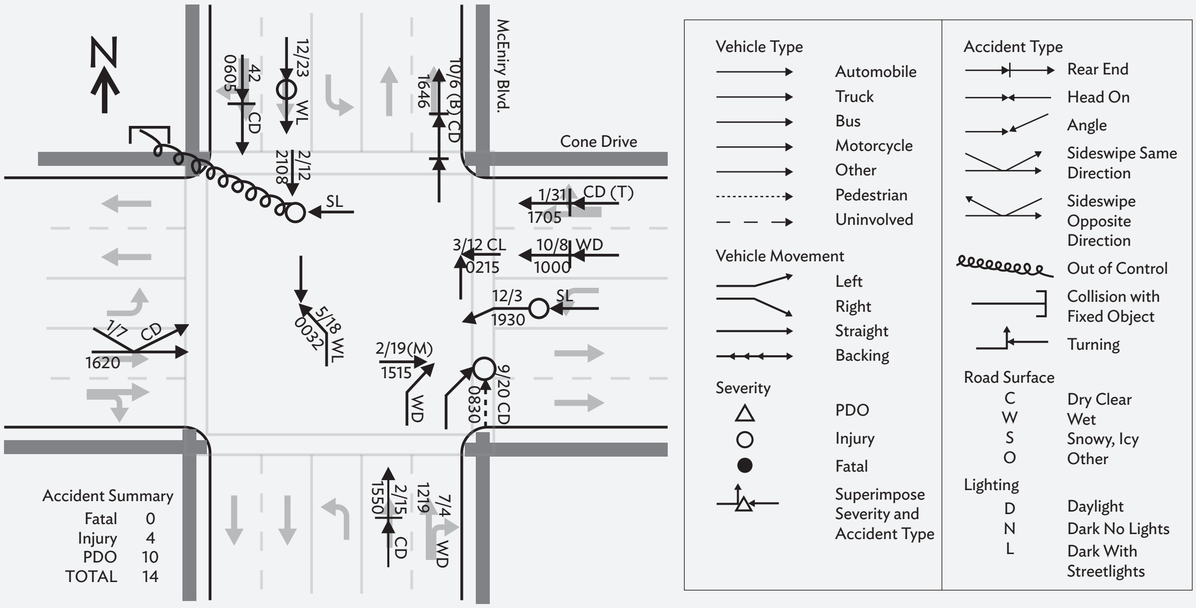
Box 5: Collision Diagrams in CAREC Countries

Generally, road crash data are collected by police forces in CAREC countries using paper-based forms. Most of them are conceived for prosecution purposes rather than for road safety engineering analysis.

While the forms used almost always include scene sketches, they are not detailed enough to create a to-scale scene diagram.

CAREC = Central Asa Regional Economic Cooperation.
Source: Consultations carried out by FRED Engineering with stakeholders in various CAREC countries between 2023 and 2024.

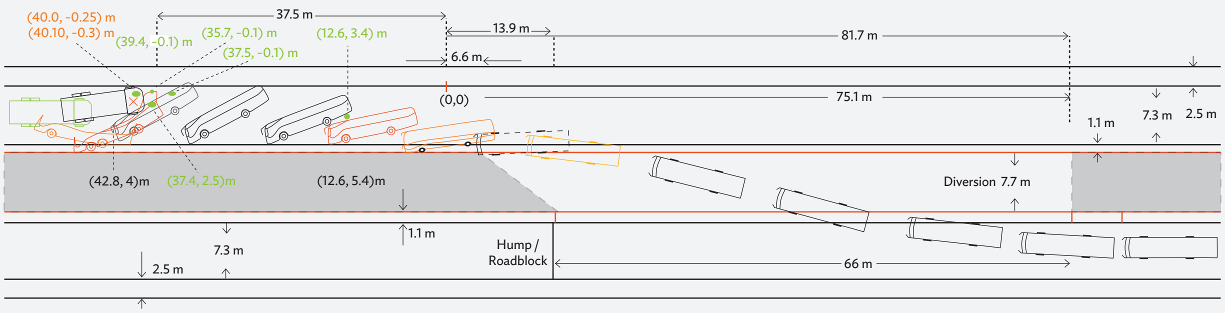
Figure 5: Example of a Collision Diagram



Source: American Association of State Highway and Transportation Officials 2010. *Highway Safety Manual.* 1st ed.

4 American Association of State Highway and Transportation Officials. 2010. *Highway Safety Manual*. 1st ed.

Figure 6: Example of a Collision Diagram Including Key Distances



Source: Automotive Design and Safety Lab, Institute of Space Technology. 2015.

2.1.6 Collection of Contributory Factors

To identify the crash contributing factors, it is recommended to use the Haddon Matrix, which allows the human, vehicle, and infrastructure factors to be divided into three time phases (Table 7):

- Pre-crash
- Crash
- Post-crash

Based on the contributory factors, solutions to a specific problem can be determined. Some solutions may be specific to a particular crash site and can be implemented immediately such as road signs, markings, removal of obstructions to vision, and basic enforcement activities. Other solutions, such as making two-wheeled vehicles more stable or safer, require more data for research and development, and may require more time, effort, and resources for implementation.

Table 7: Haddon Matrix

PHASES		FACTORS		
		Human	Vehicle	Infrastructure
PRE-CRASH	Crash prevention	• Information • Attitudes • Impairment • Enforcement of police regulations	• Roadworthiness • Working lights • Good brakes • Handling • Speed control	• Road design and layout • Speed limits • Pedestrian facilities
CRASH	Prevention of injuries during the crash	• Use of safety systems	• Crashworthiness • Crash protective design • Occupant restraint systems • Other safety devices	• Impact of protective objects on the roadside
POST-CRASH	Life support	• First-aid skills • Access to medical staff	• Access ease • Fire risk	• Relief facilities • Congestion

Source: American Association of State Highway and Transportation Officials. 2010. *Highway Safety Manual*. 1st Ed.

2.1.7 Procedures for Crash Data Collection and Investigation

A crash investigation officer should take the following actions:

- Establish that a crash occurred.
- Gather evidence and complete an objective assessment of all relevant facts about the crash. Specifically, the officer must do the following:
    - Collect and record all variables related to the crash, the road, the vehicles, and the road users by filling out the forms defined in the previous chapters according to the recommended standard definitions.
    - Draw up a collision diagram.
    - Identify and record the crash contributing factors.
    - Establish the offending party or parties.
    - Establish a link between the offender and the crash.
    - Record and report any other relevant information.

An investigating officer can make use of key sources of evidence during an investigation.[5] These include

- search of the collision scene;
- examination of exhibits, including photographing, measuring, and collecting physical evidence at the scene;
- interviewing witnesses;
- inspection of official documents (e.g., blood test results); and
- inspection of vehicles.

Searching the scene and examining the physical evidence found is a key phase of the investigation. It is essential to avoid contamination of the crash scene whenever possible. Timely handling of the crash scene ensures the preservation of physical evidence, the location of witnesses, and the apprehension of any suspects, thereby increasing the prospects of accurately reconstructing the circumstances of the crash.

2.1.8 Use of Modern Technologies for Crash Data Collection and Investigation

The incorporation of new technologies for collecting and investigating road crashes has been gaining momentum in recent years, improving the accuracy, efficiency, and completeness of crash investigations.

Some of the most impactful technologies currently in use are as follows:

Drones (Unpiloted, Uncrewed Aerial Vehicles)

Drones are widely used for documenting crash scenes. They provide a comprehensive aerial view, which is essential for accurately mapping and analyzing the site (Figure 7). Drones help clear crash sites quickly, reducing the risk of traffic congestion and collateral collisions, and improving officer safety by minimizing the time they spend on potentially dangerous roads. They can also enable the creation of detailed 3D models and orthomosaic maps, which are critical for in-depth crash analysis and court presentations.

[5] Physical evidence is concrete evidence that helps to reconstruct the crash dynamics. It includes any solid, liquid, or gaseous material that can help establish facts (e.g., tire tracks, tire skids, vehicle debris, etc.).

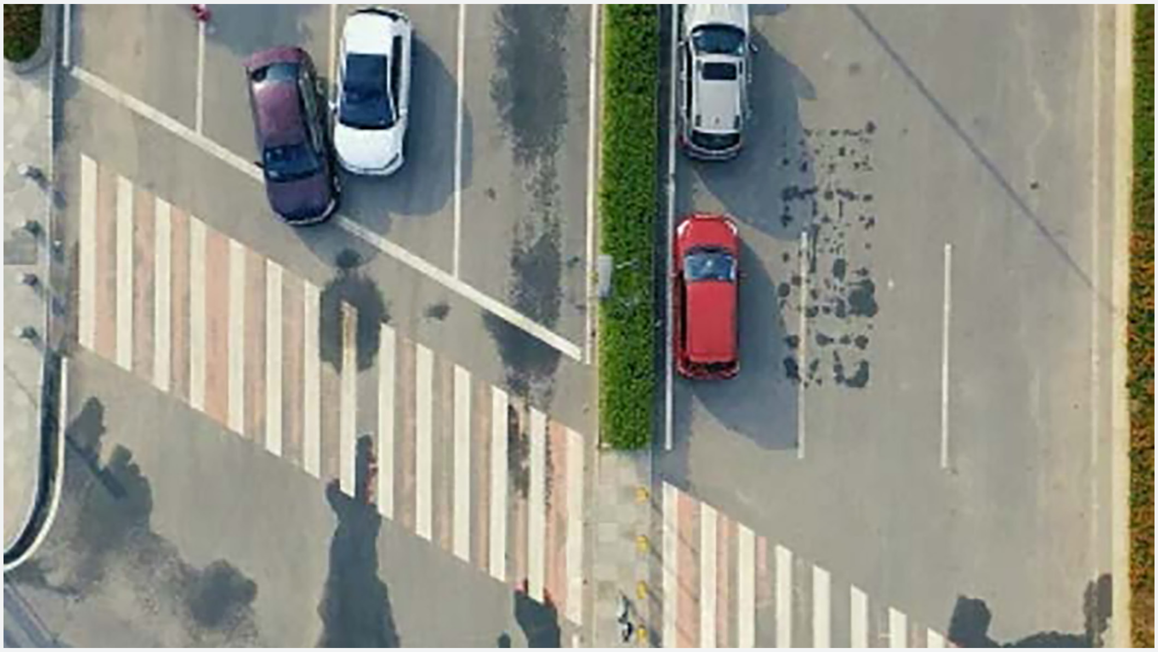
Box 6: The Use of Drones and Other Technologies in Crash Investigation in the People's Republic of China

Modern technologies for crash investigation are widely used in the People's Republic of China. These technologies include drones (unpiloted aerial vehicles), high-definition surveillance cameras, telematics systems, and 3D laser-scanning or photogrammetry.

The introduction of drones in cities such as Shenzhen has helped solve the major challenges associated with manual data collection. Using drone technology, the Shenzhen Traffic Police can automatically generate a detailed map or model of the site within a few minutes of arriving at the scene. Drones used in the People's Republic of China are typically integrated with intelligent report generators that quickly transform data collected at the scene into a model that can be exported as part of a post-crash report. An officer present at the scene must then confirm the validity of the report and sign it.

Source: DJI Enterprise

Figure 7: Example of a Crash Reconstruction with Drone



Source: DJI Enterprise.

Telematics Systems

Telematics systems are widely used, especially in commercial vehicles, to monitor real-time data on vehicle movements and driver behavior. In certain situations, these systems provide critical data that can be analyzed to understand the circumstances that led to a crash. For example, telematics data helps in identifying risky driving patterns, vehicle speed, braking behaviors, and other crucial factors that contribute to crashes. This real-time data collection can be invaluable for crash investigations and for developing preventative measures.

Black Boxes

Black boxes or event data recorders are devices installed in vehicles to record technical information during a crash event. Data captured typically includes vehicle speed, accelerator position, brake usage, seat belt status, and airbag deployment. This information is crucial for reconstructing road crashes and determining causative factors.

Box 7: The Use of Black Boxes in the United States

In the United States, black boxes have been instrumental in legal proceedings. For instance, in 2007, the black box in New Jersey Governor Jon Corzine's SUV revealed that the vehicle was traveling at approximately 91 miles per hour 5 seconds before a crash, significantly exceeding the 65 miles per hour speed limit. This data was pivotal in understanding the circumstances leading to the crash.

Source: New Jersey State Police

High-Definition Surveillance Cameras

High-definition cameras can be installed at strategic locations to continuously capture traffic conditions and crashes. This technology can be used to provide clear evidence of road conditions, vehicle speeds, and the actions of drivers involved in crashes. The main limitation of these tools is their limited coverage of the road network, so the locations where to install them must be selected with great care.

Vehicle Dashcams

The integration of dashcams into vehicles has proven to be a significant advancement in road safety and legal clarity. They offer unbiased, real-time evidence that aids in accurately reconstructing events, determining fault, and ensuring justice in post-crash investigations. As technology continues to evolve, the role of dashcams is likely to expand, further solidifying their place as an essential tool in modern vehicular safety and accountability.

Dashcams provide real-time recordings of vehicular journeys, offering objective evidence that can clarify the circumstances leading to crashes. Their utility spans from aiding law enforcement in reconstructing events to protecting drivers against fraudulent claims.

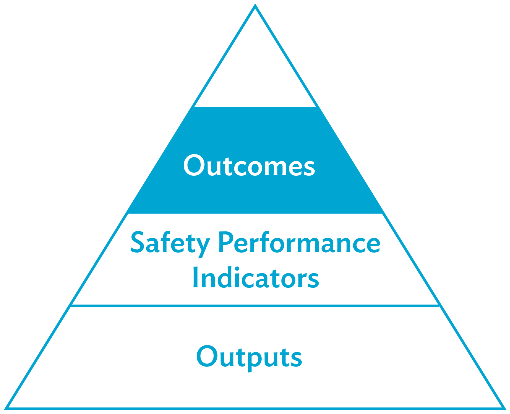
Box 8: The Use of Dashcams in the People's Republic of China

The People's Republic of China has one of the largest dashcam markets worldwide. These kinds of devices started gaining massive popularity for insurance and especially road safety reasons. In fact, according to 2013 statistics, the estimated number of crash fatalities was 18.8 per 100,000 inhabitants, which was significantly higher than in developed Western countries, such as the United States (10.6), Canada (6.0), or the United Kingdom (2.9).

Nowadays, in the People's Republic of China, public transportation and commercial vehicles are required to install dashcams to assist in identifying the causes of road crashes.

Source: IEEE Acess. https://ieeeaccess.ieee.org/

2.2 Risk Exposure Data



To have greater impact in road safety decision-making processes, crash data should be supplemented with data on the safety performance of the road traffic system (e.g., data on risk exposure and safety performance indicators). This section provides guidelines for the collection, availability, and processing of **risk exposure data**.

2.2.1 Types of Risk Exposure Data

The number of crashes occurring in a country greatly depends on its socioeconomic characteristics. To obtain an estimate of risk, it is suggested to adopt as reference the ratio between the number of traffic casualties and the amount of exposure, which can be the population, the volume of traffic, or the number of registered vehicles.

The main exposure measures related to road safety are described in Table 8.

Table 8: Risk Exposure Measures

Risk Exposure Category	Definition	Unit
Length of the road	Line of communication primarily used by motor vehicles	km
Kilometers (km) traveled by vehicles	Total km traveled by motor vehicles in a country	Vehicles × km
Kilometers traveled by persons	Total km traveled by persons within the borders of a country	Persons × km
Consumption of fuel	Total energy consumed by motor vehicles within the borders of a country	Terajoules (TJ)
Population	Number of inhabitants of a country (temporary visitors, tourists, or undocumented immigrants are not counted)	Number of persons
Number of drivers	Person in possession of a driving license; does not necessarily have to be in possession of a vehicle	Number of persons
Fleet of vehicles	Total number of registered motor vehicles within a country	Number of motor vehicles
Number of travels	Total number of travels made by persons within a country. A travel involving return is counted twice.	Number of trips
Time spent in traffic	Total time spent by persons on a country's infrastructure	Unit of time (hours, minutes, and seconds)

Source: Government of the United States, Department of Transportation. Federal Highway Administration.

2.2.2 Use of Risk Exposure Data

Given a specific exposure, "risk" is the expected outcome for road safety analyses. The outcome may be as follows:

- The number of crash casualties of a certain type.
- Monetary loss due to the consequences of crashes.

In the field of road safety, risk can be defined as follows:

Risk = road safety outcome/amount of exposure

The outcome of road safety means the amount of road crashes or crash casualties (fatal crashes, crashes resulting in hospitalized or fatally injured victims, etc.).

Box 9: Risk Exposure Data in Kazakhstan

The Traffic Police in Kazakhstan collects crash and casualty data, while the Ministry of Transport collects other types of data, such as the vehicles number and the volumes of traffic.

In the quarterly reports prepared by the Ministry of Transport, these two types of data are combined to analyze crash risk exposure. However, these analyses are not exhaustive; no correlation is made, for instance, between the number of crashes and traffic data such as distance traveled annually by vehicles or passengers.

Source: Consultations carried out by FRED Engineering with the Administrative Police of the Ministry of Internal Affairs and the Committee of Roads of Kazakhstan in 2024.

The exposure measures listed in the previous section can be grouped into two categories:

- **Estimates of traffic.** Length of the infrastructure, kilometers traveled by vehicles, consumption of fuel, fleet of vehicles.
- **Person-at-risk estimates.** Kilometers traveled by persons, population, number of travels, time spent in traffic, number of drivers.

When estimating risk, the amount of exposure should be computed by applying the same restrictions considered for road safety outcome data (e.g., same time interval, same area, types of users relevant to the type of crash being analyzed, etc.).

Each exposure measure has advantages and limitations:

- **Kilometers traveled by vehicles.** This exposure measure has the advantage of being available at a considerable disaggregation level: by time, type of vehicle, type of road, driver features, etc. It is possible to estimate the traffic density by combining this measure with the length of the infrastructure (i.e., the number of kilometers traveled by vehicles divided by the infrastructure length). Kilometers traveled by vehicles and crash counts are two measures that are often used together. However, the availability and the level of disaggregation of the measure can widely vary and are constrained by the type and the characteristics of the collection method. For example, vehicle kilometers traveled obtained from traffic counts are usually available by infrastructure and vehicle characteristics, while disaggregation by person characteristics is only possible through data obtained from travel surveys.

- **Kilometers traveled by persons.** The application of this exposure measure is mainly oriented toward victim counts. Kilometers traveled by persons can be obtained from kilometers traveled by vehicles (and vice versa), as the estimation of these two types of exposure measures is derived from the same sources of data (e.g., counts of traffic, surveys of vehicle movements). This measure (as opposed to kilometers traveled by vehicles) considers the category of road user (driver or passenger) or the purpose of the trip.
- **Length of the infrastructure.** This is an elementary exposure measure since it does not capture time changes in the use of roads in a specific location. In addition, the measure could be affected by the economic influences related to the planning and development of the infrastructure network.
- **Consumption of fuel.** This exposure measure is used for estimating vehicle-kilometers. However, it does not capture short-term fluctuations in the use of roads.
- **Fleet of vehicles.** Another option to vehicle-kilometers is the vehicle fleet. Vehicle information, such as type, age, and physical features are generally available for this indicator. The definition of vehicle fleet should also include light, low-powered vehicles such as mopeds, e-bikes, and scooters, as they also participate in road traffic, especially in urban areas.
- **Population.** Population data are relatively reliable; they may be available for several variables, like age, gender, and different road user groups such as children, students, professional drivers, etc.
- **Number of drivers.** Like vehicle fleet, this indicator refers to the amount of traffic within the borders of a country. The measure is aimed at sharing as much population data as possible, but may also provide an estimate of the behavioral characteristics of drivers as well as their experience. When considering casualties, this type of data may be used similarly to population data.
- **Number of travels.** Number of travels and number of kilometers traveled by persons are based on the same sources; therefore, the same disaggregation level is available. Additional information is provided by dividing the number of travels by the number of drivers.
- **Time spent in traffic.** This indicator takes into account the number of kilometers traveled by persons, rather than the number of travels. It explains the trend in average travel speed. However, difficulties may arise in performing the disaggregation of time spent in traffic, especially in comparisons. For example, it can be complicated to compare time spent in traffic on a motorway with time spent in traffic in an urban area.

2.2.3 Methods for Collecting Risk Exposure Data

There are several methods that can be used for risk exposure data collection.

Travel Surveys

By monitoring the activities of each member of the population for a given period of time, the travel patterns of the population can be obtained. However, carrying out such measurements can be complex, and such level of exhaustiveness and accuracy is not necessary for road safety analysis. Another option is to investigate a portion of the surveyed population.

Each survey aims to obtain information about a target population, which can be individuals, households, owners of vehicles, etc. In any case, the sample chosen must be representative of the entire target population.

Data reported by travel survey respondents may be related to these exposure measures:

- Distance traveled.
- Time spent in traffic.
- Number of travels.

Some additional information may be included:

- Number of vehicles currently in use.
- Number of people who hold a driver's license.
- Number of active drivers.
- Occupancy of vehicles.

This information is generally available by mode of travel.

Travel surveys have persons as units, which is an advantage since it allows the distribution of exposure data according to persons' features such as age, gender, years of driving experience, and nationality. A high disaggregation level can be achieved by using the described framework. In particular, travel surveys allow to combine comparisons per person, vehicle, and network characteristics.

Traffic Count Systems

Counting procedures can be based on human observations or the use of machines. Human observations allow for the classification of vehicles effectively; however, they are expensive and work properly only on stretches with limited traffic intensity.

Vehicle-kilometers traveled in a specific time unit can be obtained by multiplying the number of vehicles counted during this time unit and the section length. From the sum of the products for the different road sections, the total number of vehicle-kilometers in the specified unit of time can be derived.

By surveying all vehicles passing on a stretch of road, traffic count systems allow the calculation of some basic measures such as volume of traffic, average annual daily traffic, and kilometers traveled by vehicles. This information is generally available by vehicle type and road type.

These traffic count systems allow for a continuity of measurements over time. However, this technique has some limitations:

- Only vehicles are counted.
- Local and urban roads are generally not included; therefore, it is possible that measurement points may not correctly represent national and/or regional traffic.
- Comparisons between groups of persons with different characteristics are not possible.
- Comparison between vehicle-kilometers estimated from traffic counts with those estimated from travel surveys is not straightforward.

Vehicle Fleet Databases

Vehicle fleet data (e.g., number of vehicles registered or number of vehicles on the road) can be used as a measure of exposure when kilometers traveled by vehicles are not available. Two different ways can be followed to collect vehicle fleet data:

- By collecting vehicle ownership data through surveys.
- By means of various vehicle-related databases:
  - Databases of vehicle taxation.
  - Databases of vehicle registration.
  - Data of vehicle inspection.
  - License plate records.

The number of registered vehicles is the most widely used exposure measure as this is easily accessible. However, it is possible that not all vehicles may be registered in the same database; this exception usually applies to mopeds and light motorcycles. In addition, the number of the license plate may be linked to the license of the drivers (and not to the registration of the vehicle).

A license plate identification database can only be useful if each vehicle has a unique license plate identification. A factor that could limit the accuracy of the data is the recording timeliness; newly registered vehicles should be included after a short time of being put on the road, and vehicles no longer in use should be deleted from the records.

The number of vehicles in use can be effectively represented by vehicle taxation databases and vehicle inspection information, which can also be used to correct any inaccuracies reported in vehicle registers.

Variables collected are related to the type, brand, weight, and registration date of the vehicle.

In any case, the number of registered vehicles allows only a rough estimation of exposure, which implies constant maintenance and updating of registers. In addition, fleet data do not allow for disaggregation by person or driver characteristics.

Box 10: Safety Performance Indicators Data in the CAREC Region

Most CAREC countries do not collect data on safety performance indicators and do not maintain a repository of such information.

However, some countries (Azerbaijan, the People's Republic of China, Georgia, Kazakhstan, Mongolia, Tajikistan, and Uzbekistan) are active in performing road infrastructure risk assessments using the International Road Assessment Programme methodology. Outputs of these assessments can be valuable to identify the percentage of distance traveled on roads with a safety score above a minimum threshold.

Source: Consultations carried out by FRED Engineering with stakeholders in various CAREC countries between 2023 and 2024; iRAP

Driver License Database

The number of drivers allows for the collection of information on the number of drivers. This type of information can be collected through two possible approaches:

- By collecting driver's license holders or active drivers through surveys.
- By leveraging the national driving license registers.

This system allows the classification of the exposure data derived per driver features such as gender, age, and years of driving experience. Additional information such as traffic offenses can be recorded.

These exposure measures, however, are only related to drivers and not all road users. Drivers of mopeds or e-scooters could not be recorded as well.

2.3 Safety Performance Indicators

The transport system consists of **road users, infrastructure** used by road users, and **vehicles** running on the infrastructure. The safety performance of the system depends on these components.

By monitoring progress in road safety in terms of crash and casualty data, critical operating conditions in the system of road traffic can be identified. However, they are only a small part of significant measurements. **Safety performance indicators** (SPIs) better reflect road safety management in a country. They may refer to any element of the road traffic system and may cover the road infrastructure, the vehicles, and the road users.

2.3.1 Definitions and Applications Areas for Safety Performance Indicators

SPIs can be linked to infrastructure and vehicle conditions, behavior of road users, and post-crash care. The selection of SPIs to be considered (and when possible, added to a road crash data management system) depends on a country's road safety policies and on the main risks of crashes. Here are some examples:

- **Road infrastructure**: level of risk related to road attributes (e.g., iRAP star rating).[6]
- **Road users**: percentage of vehicles' occupants wearing a seat belt, percentage of motorcycles' riders wearing a helmet, percentage of drivers using mobile phone while driving, etc.
- **Vehicles**: percentage of vehicles equipped with active safety features (e.g., anti-lock braking system, electronic stability control, etc.).

The European Commission has developed a list of SPIs for road safety to better understand the different aspects that influence overall safety performance.[7] A minimum set of performance indicators can be used as reference for collection within a country. It combines optimal information and practical feasibility (Table 9).

[6] The International Road Assessment Programme. https://irap.org/.
[7] European Commission. Key performance indicators.

Table 9: Safety Performance Indicators for Road Safety with Definitions

SPI	Definition
Speed	Percentage of vehicles traveling without breaking the speed limit
Safety belt	Percentage of vehicle occupants making proper use of safety belt or child restraint systems
Protective equipment	Percentage of riders of motorcyclists and cyclists wearing helmets
Alcohol	Percentage of drivers driving within the legal blood alcohol limits
Distraction	Percentage of drivers and pedestrians not using a portable mobile device
Vehicle safety	Percentage of new cars with a Euro New Car Assessment Programme safety rating equal to or above a predefined threshold
Infrastructure	Percentage of distance traveled on roads with a safety score above a predefined threshold
Post-crash care	Time elapsed between the emergency call following a road crash and the arrival of the emergency services at the crash scene

SPI = safety performance indicators.

Source: Mobility and Transport Department. European Commission.

2.3.2 SPI Data Collection Methodologies

Since roadside observations are required for different SPIs, it is necessary to follow some rules when considering data collection for an indicator:

- **Time**. If rates differ between day and night, week and weekend (e.g., for alcohol), and between different seasons (e.g., pedestrian and bicycle counts), meaningful periods should be established based on their actual share of traffic. If rates do not differ (e.g., distraction and seat belt use), daytime measurements with a reference period of 1 year may be accepted.
- **Place**. A distinction should be made between different types of cities and different types of roads. These categories should be included in proportion to their share of traffic. In any case, it is recommended to observe about 1,000 vehicles in each category. Sampling often involves the same number of vehicles for each significant level (e.g., type of road, type of period or region, rather than different sample sizes based on their share of traffic). In this case, when calculating the national average, each level should be weighted according to its actual size. Sometimes, there is intentional oversizing of some types of road locations, periods, or types of vehicles. For example, in the case of driving under the influence of alcohol and drugs, weekend nights can be a significant period. Therefore, even if there is only a limited percentage of traffic during these periods, the sample should be large enough to allow analysis of driver characteristics. In overall analyses, such as for different periods of the week, it is necessary to apply weighting to allow oversampling correction.
- **Observations**. For the purpose of observation, vehicles should be selected randomly. Generally, the police focus on suspicious-looking drivers, which therefore does not lead to a representative measurement. Rather, vehicles must be rigorously checked upon arrival at the measurement site. For each selected vehicle, all the expected variables should be reported before moving to the following vehicle. It is possible to skip vehicles, but it is essential to avoid incomplete records.

2.4 National Central Road Safety Database and Data Sharing

Although each agency responsible for collecting road safety data typically has its own database, it is essential that all data are also collected and validated within a national central database. Sending data to the central database should be among the responsibilities of each agency that collects them, while validating and sharing the data should be among the responsibilities of the agency hosting and managing the database.

A standardized process for collecting, storing, processing, and using data should be established at the national level. The process should involve all relevant stakeholders and include the following aspects:

- The data should be recorded in a common information system (directly from the field or from office by transferring paper-based forms into the database).
- The data should be regularly transferred to a central data repository where data from all sources are consolidated (national database).
- The information included in the database should concern road crash and casualty data, risk exposure data, SPIs, and other road safety data deemed necessary.
- The common information system and national database should be accessible by those responsible for data collection (e.g., police, health sector, and insurance companies) and by those responsible for planning and implementing road safety interventions or developing road safety policies. This is highly important for data-driven decision-making.
- The database should be fed by analysis tools. The data per se are useless if they cannot be analyzed and used to inform decision-makers. A road safety data management system should be in place, allowing for a number of analyses: querying of data, mapping data, obtaining graphics and reports, etc.

A national database must have the characteristics shown in Figure 8. It serves the needs of multiple stakeholders so that they can feed, correct, modify, enrich, and query the database. However, it may happen that by integrating data from different sources into a single database, duplications are produced. Therefore, a mechanism should be established to deal with duplicate records. A dedicated office should be established to monitor the quality of stored data.

In the database system management, several roles can be identified:

- Contributors: Usually represented by police and medical facilities, they are responsible for collecting and providing the necessary data for the database.
- Editors: In charge of entering the collected data into the database.
- Administrators: In charge of managing database consistency and assigning access rights.
- Validators: In charge of supervising the validity of data.

Figure 8 : Main Aspects of a National Road Crash Database

Data

- Data should be voluminous and comprehensive to include all system characteristics and allow for complete and exhaustive analysis
- Data should be structured and well organized within the database, so as to facilitate its management and analysis

Database

- The database should be centralized and contain data from multiple official sources
- Must minimize data redundancy (by setting up automatic or manual database control mechanisms)
- Must allow linking of different data (either data of the same nature collected by different sources, or data of a different nature to be integrated with each other for better understanding of the situation)
- Must be accessible by all relevant stakeholders

Stakeholders

- Stakholders must be able to feed the database
- They must be able to correct, modify, or enrich data in the database
- They must be able to make queries to the database for their own purposes

Source: Road Safety Management. PIARC (World Road Association).

2.5 Health and Safety During Crash Data Collection and Investigation

2.5.1 Safety at the Crash Scene

Ensuring safety at a crash scene is a primary requirement. When dedicated units (e.g., police, ambulance, fire brigade) rush to the crash scene, the following aspects should be considered (Table 10).

Table 10: Crash Scene Safety Requirements

Section	Actions to Implement
Mobilizing	• Assessment of traffic levels and possible access difficulties • Identification of the number and type of vehicles and victims • Assessment of the presence of any hazardous or flammable materials
Arrival	• If two teams are involved, they should approach from opposite directions. • Preliminary inspection, including a dynamic risk assessment
Positioning appliances	• Park in the override position to block the relevant lane. • If there are two appliances, the second should be parked in the blocking position beyond the crash. The smaller or lighter vehicle should be parked on the side of the crash less exposed to traffic. • It may be necessary to close the road in case of narrow roads or to ensure the safety of personnel on busy roads.

continued on next page

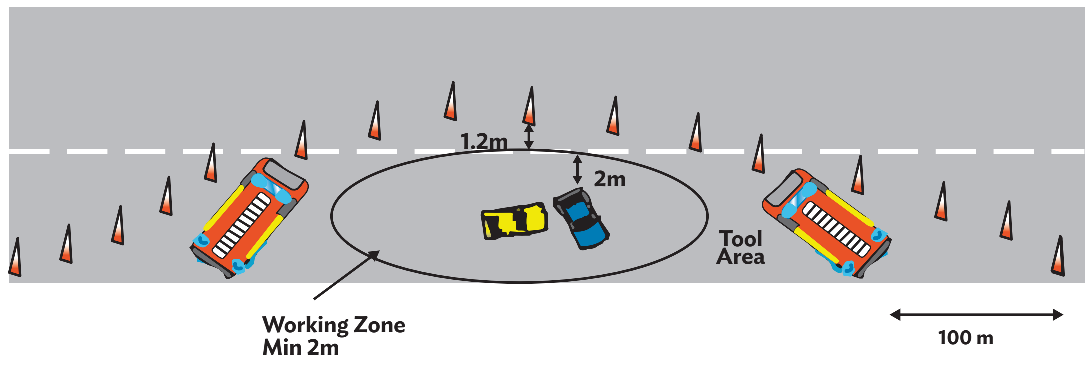
Table 10 *continued*

Section	Actions to Implement
Signs	• Placement of warning signs approximately 200–400 meters (m) away from the crash • When placing signs, consider the view of drivers and consider any bend, dip, or rise, as well as weather conditions such as ice, fog, rain. • On wider or faster roads, signs should be located further from the crash than smaller roads. • Attention should be paid to approaching traffic; a car traveling at a speed of 112 kilometers per hour covers 31 m in 1 second. • Signs should be left in place until traffic police leave the crash scene.
Cones	• Isolate the protection area to a safe distance beyond the crash. • Red and white tape should be placed between the cones to prevent emergency personnel from passing from the work area to the boundary line. • The work area should be at least 2 m around the vehicles involved. • A lateral safety margin of 1.2 m should be provided between the work area and the cones. • If it is not possible to guarantee the safety margin outside the work area, the road should be closed to through traffic. • Consideration should be given to temporarily closing the road during the creation of the work zone. • Cones should be positioned to form a trough from the edge of the carriageway 100 m before the work zone. • If more lanes are involved, the cones should be extended 100 m for each lane. • Directional arrows and cones can be used simultaneously. • Additional lighting for signals, cones, and protective devices (especially in case of poor visibility) should be considered.
Fire cover	• Extend a hose reel to the crash scene. • Place a fire extinguisher near vehicles. • Attention should be paid to the fire risk when conducting the initial survey of the crash scene, particularly in case of overturned vehicles.
Lighting	• Appliance vehicles parked in the idle position should have their blue flashing lights on. • Excessive and unnecessary use of emergency lights at the crash scene may have a negative effect on traffic. • Illumination of warning signs may be useful. • The use of vehicle emergency lights may be useful; however, it should be ensured that they do not obscure the visibility of blue flashing lights. • The use of portable lights and generators to improve the illumination of the crash scene should be considered. • The use of lighting towers may be useful to improve the safety of personnel at the scene.
Traffic control	• It is necessary for moving traffic to not cross the area where the firefighters are operating. • Traffic should be stopped until signs are in place and firefighting equipment, cones, and safety margins are properly positioned. • If is not possible to keep the working area free from traffic and a safety margin of 1.2 m around vehicles, the road should be closed. • The minimum required width for single-lane traffic is 3 m. • Signs or cones should always face traffic on the carriageway. • Traffic should be slowed by using restricting cones, which should be placed in the center of the carriageway. • A STOP/GO system may be considered. • Firefighters who control traffic must be visible; they should wear high-visibility jackets and possibly be in possession of a flashlight or lighted baton.

Source: Government of Ireland, National Directorate for Fire and Emergency Management. 2009. *Road Traffic Accident Handbook.*

An example layout of a road traffic crash scene is shown in Figure 9.

Figure 9: Sample Layout of a Road Traffic Crash Scene



m = meters.
Source: Government of Ireland, National Directorate for Fire and Emergency Management. 2009. *Road Traffic Accident Handbook*.

2.5.2 Personnel Safety

All officers attending the crash scene must be provided with personal protective equipment to safeguard their health and safety. The minimum requirements for such equipment at a crash scene are as follows:

- High-visibility jacket, vest, or surcoat according to EN 471:2003 standard.
- Protective clothing and gloves to avoid injuries from sharp edges.
- Surgical gloves for the treatment of victims.
- Additional equipment such as head protection devices, safety boots with protective toe cap, safety glasses with helmet visor, respiratory protection devices, and ear defenders.
- Other equipment protecting from dangers presented by batteries in electric vehicles.

3 Data Analysis

Data analysis is a fundamental part of crash investigation procedures and is at the core of an evidence-based decision-making approach. An adequate crash data analysis extracts the most benefit from the collected data. By leveraging data effectively, the data analysis would unravel the complexities surrounding road crash and casualty data, and allow for a transition from a broad overview of road safety concerns to a more focused and detailed examination of specific issues.

Data analysis is crucial for understanding the causes of the crashes, and starts from *data collection*, as shown in Figure 10. The analysis is then divided into two main phases: the *diagnosis of data and variables* and the *selection of countermeasures for a critical location*.

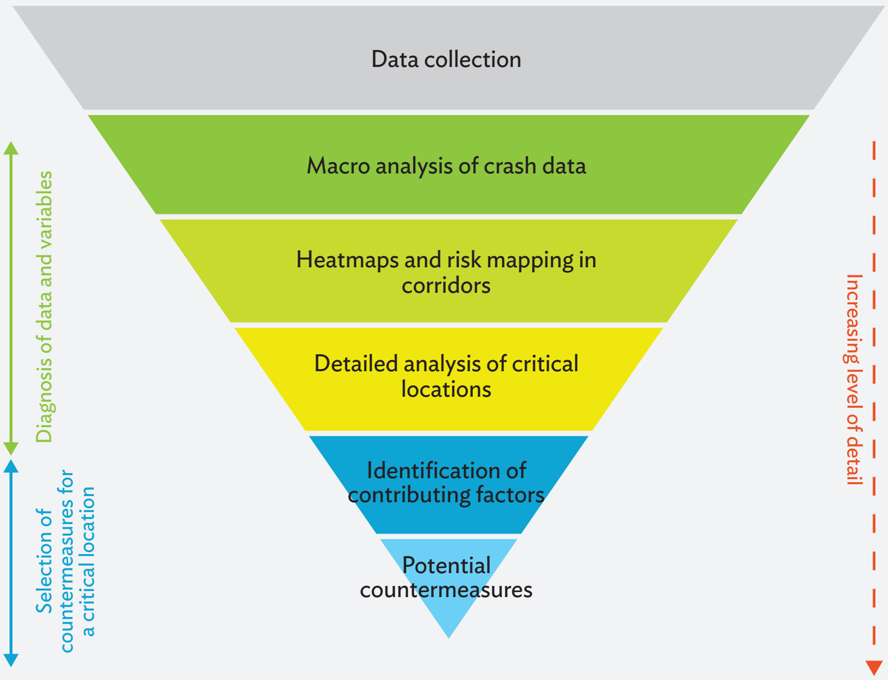
The ***diagnosis of data and variables*** begins with a macro analysis of crash data, which allows investigators to identify general trends and patterns that may indicate systemic issues or recurring problems at a national and regional levels. Subsequently, the heatmaps and risk mapping of road corridors will identify the most critical locations on a road network, for instance, through using geographic information system (GIS) software and spatial data. Finally, the diagnosis phase concludes with a detailed analysis of the previously found critical locations.

The ***selection of countermeasures for a critical location*** begins with the identification of factors leading to road crashes, such as the human factors, the vehicle factors, and the roadway factors. The analysis concludes with the identification of potential countermeasures to address the previously detected contributing factors. In general, this reactive approach allows for the crash investigation to draw conclusions based on data rather than speculation.

A comprehensive training framework for personnel involved in the crash investigation could ensure that they are able to adequately deal with the complexities related to the crash data analysis. A possible thorough training could be composed of the following key components:

- Basics in data management, data cleaning, and data validation.
- Foundational knowledge in crash statistics and visualization.
- GIS principles.
- Spatial analysis procedures on GIS.
- Essentials in the identification of contributing factors and potential countermeasures.
- Hands-on training sessions.

Figure 10: Data Analysis Pyramid



Source: FRED Engineering.

3.1 Diagnosis of Data and Variables

The diagnosis of data extracts the most important insights from the previously collected information and ensures that the road safety recommendations given are data driven. The analysis should start with general statistics in the country and each territory inside of it (e.g., provinces, departments, etc.), and then should be complemented with crash risk maps and heatmaps to find out the most critical intersections and corridors. Finally, specific data from these critical locations should be revised to provide tailored countermeasures.

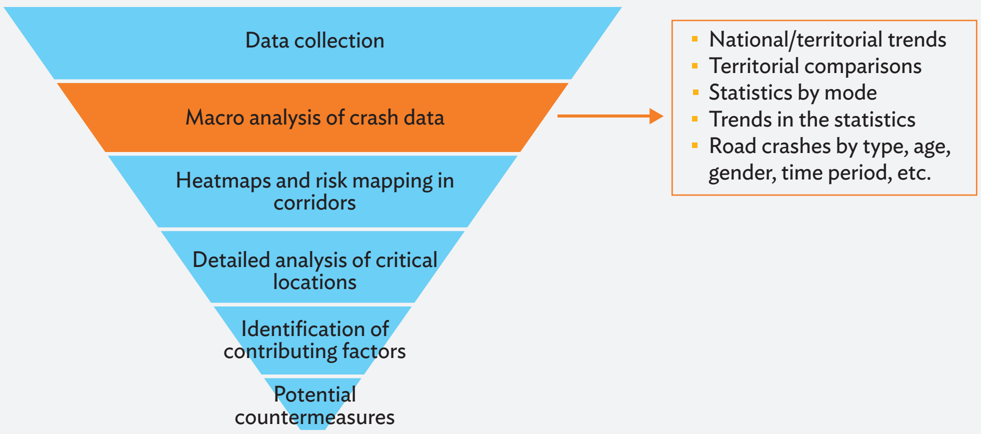
3.1.1 Macro Analysis of Crash Data

The first important step in the data analysis for the crash investigation is to analyze the general trends and statistics of road crashes in the country and each the territories at a macro level (Figure 11). This first step visualizes the overall road safety landscape and understands the global and most critical issues that need to be considered on all levels.

When dealing with road crash and casualty data, two-factor or multiple-factor analysis can be made. The following chapters provide some examples of possible analysis, but should not be considered exhaustive. The specific analysis to be made based on available data depends on the specific context and needs according to analyst expertise. It is recommended to explore all possible analysis and cross-relations among variables. However, for decision-making purposes, only the information highlighting a road safety problem should be used. The analyst should always keep in mind that the main objective of such analysis is identifying problems and taking corrective actions, rather than just preparing statistics.

National and Territorial Trends

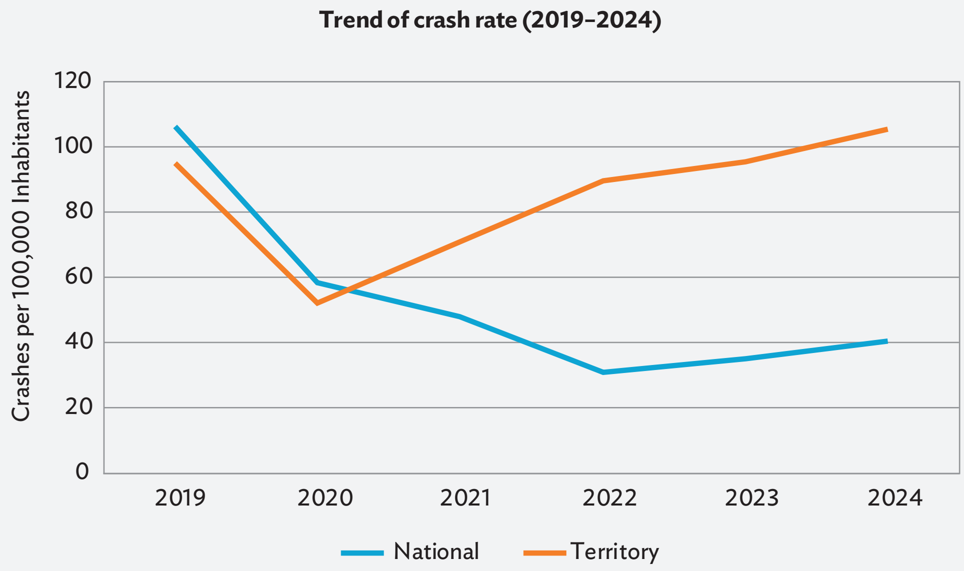
Figure 11: Macro Analysis of Crash Data



Source: FRED Engineering.

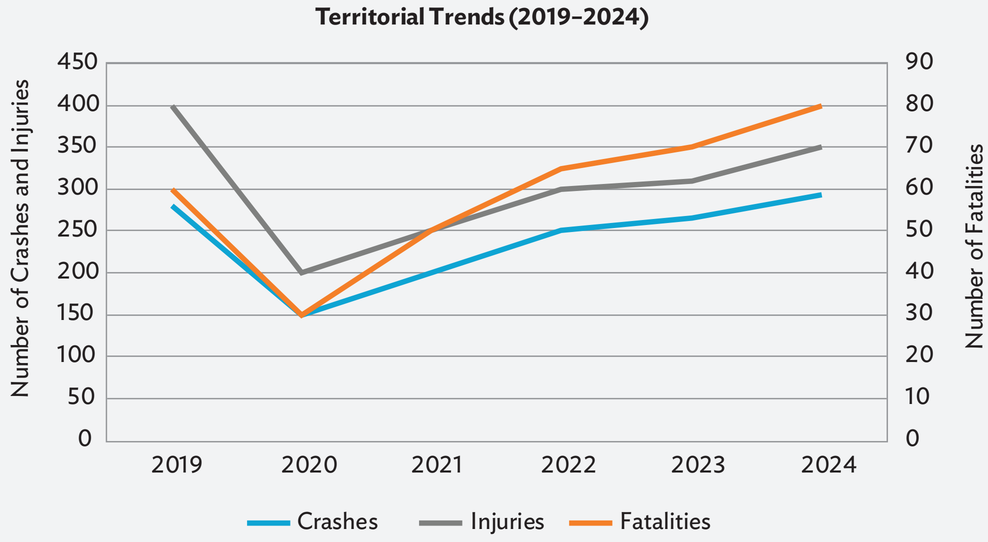
National trends give a complete picture of the overall road safety landscape of a country, particularly highlighting whether the number of road crashes and crash casualties has increased in recent years. By comparing regional trends with the national trajectory, it becomes possible to discern any distinct patterns or variations in behavior within specific regions. As shown in Figure 12 and in Figure 13, a graph that reflects how the number of road crashes and crash casualties has varied in recent years, serves as an initial snapshot of the road safety trends within the analyzed region.

Figure 12: Sample Graph of Crash Rate Trends



Source: FRED Engineering, 2024

Figure 13: Sample Graph of Territorial Trends

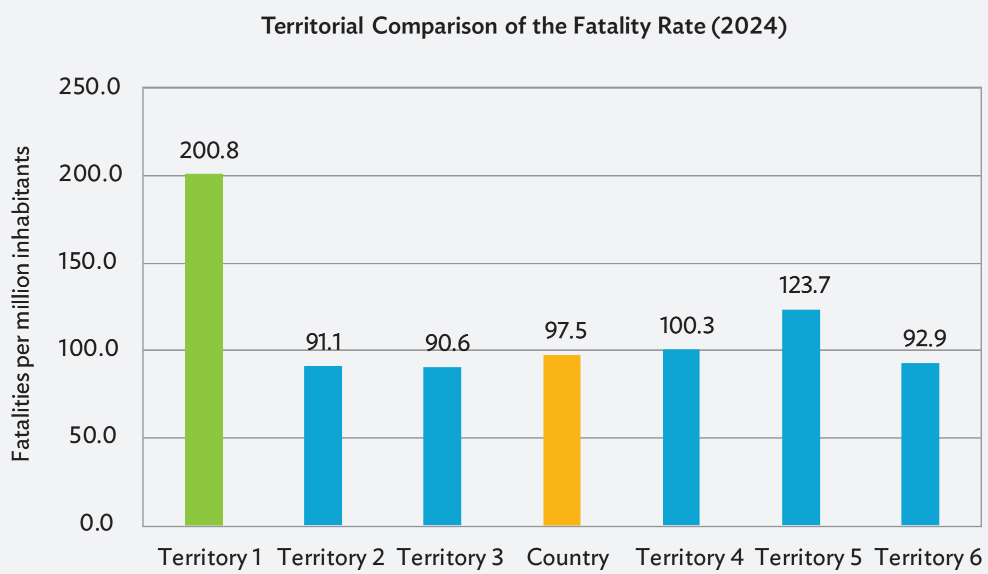


Source: FRED Engineering, 2024

Territorial Comparisons

Comparison graphs with important statistics such as the crash rates, injury rates, and fatality rates allow comparisons among territories within a country to determine critical areas that need to be prioritized, as shown in Figure 14.

Figure 14: Sample Graph of Territorial Comparisons

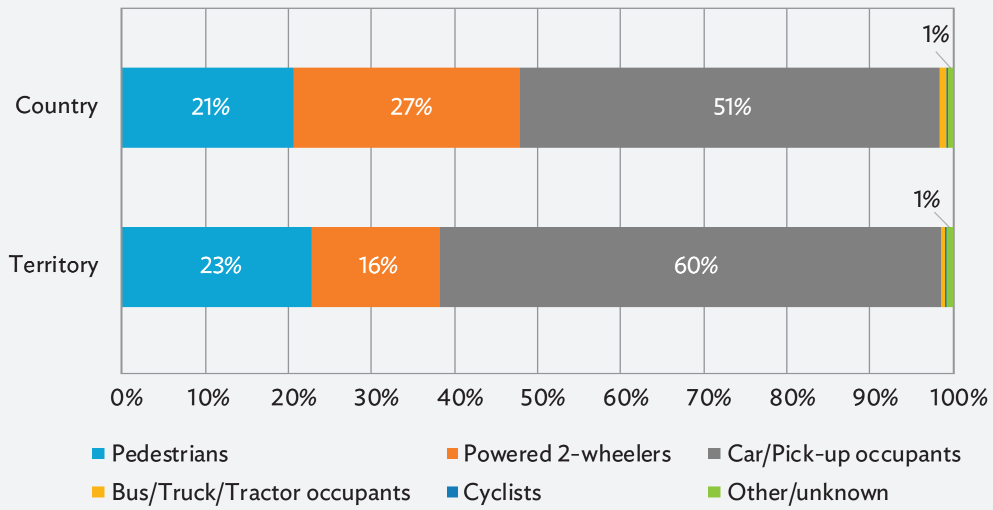


Source: FRED Engineering, 2024.

Statistics by Mode

Aggregate statistics on victims and crashes categorized by mode of transportation provide insight into the most exposed user groups. In particular, the percentage or fatalities by transport mode is a fundamental statistic needed for an adequate diagnosis of data. Additionally, contrasting these figures with national averages within the same graph offers a rapid assessment of potential disparities, as shown in Figure 15.

Figure 15: Sample Graph of Statistics by Transport Mode

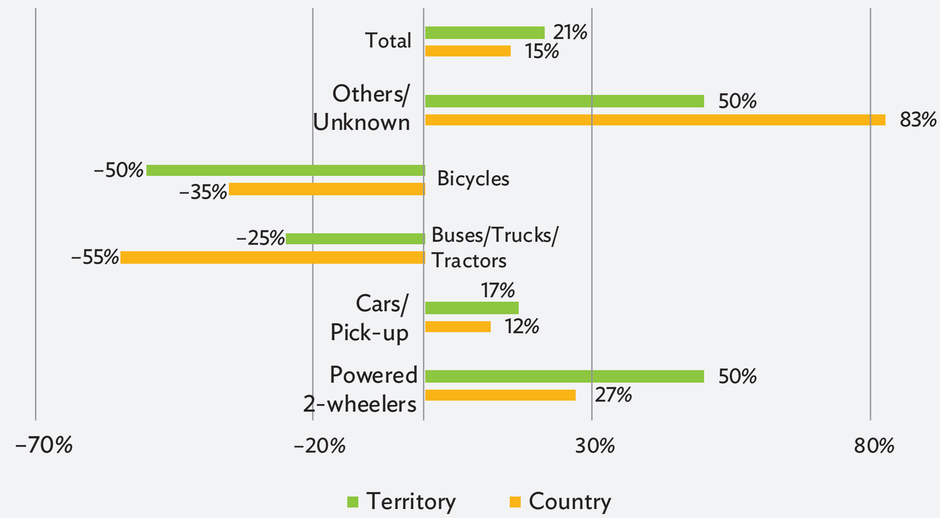


Source: FRED Engineering, 2024.

Trends in the Statistics

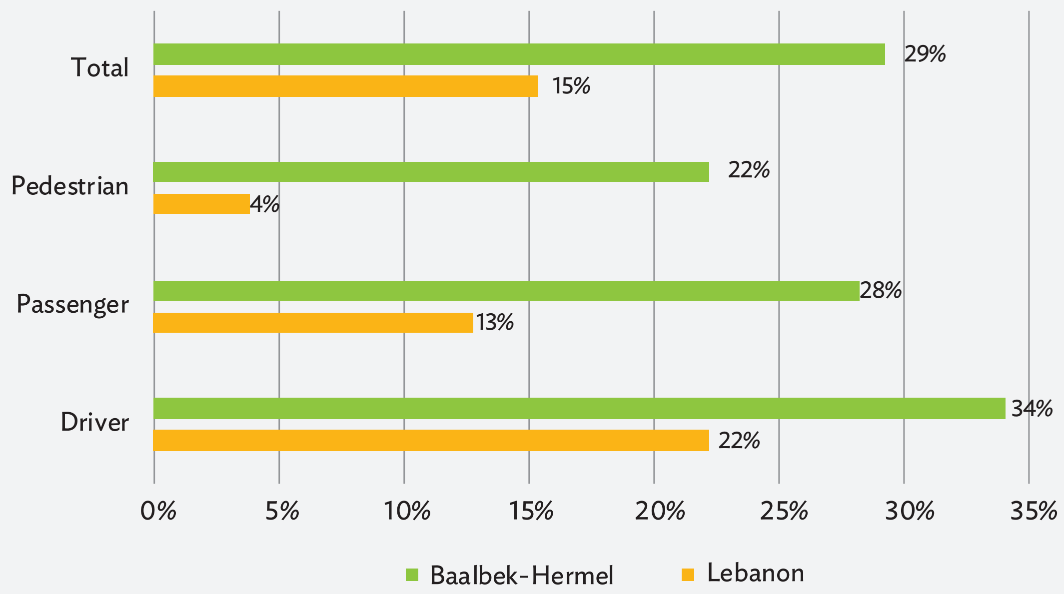
Trend graphs that compare data from the most recent year with a base year allow for a more direct visualization of the changes that some specific road safety values have had during that period. It is important to take as reference 2 years (or time periods) that have had a good quality in the data collection procedures, to avoid bias in the analysis. For example, in several countries, the year 2020 cannot be used due to the bias generated by the coronavirus disease pandemic. Some of the trend graphs that can be built are on victims by type of vehicle (Figure 16) and by type of road user (Figure 17).

Figure 16: Sample Trend Graph of Victims by Type of Vehicle



Source: FRED Engineering, 2024.

Figure 17: Sample Trend Graph of Victims by Type of Road User

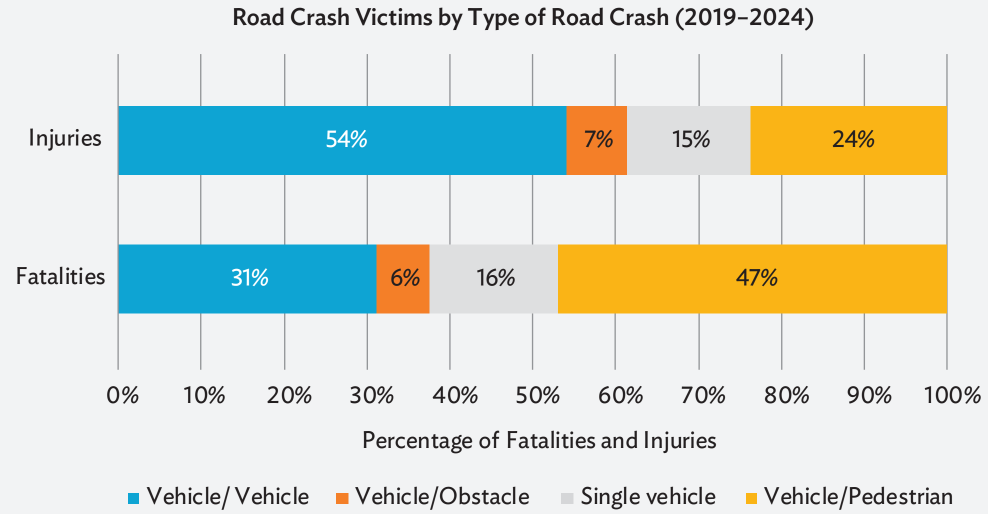


Source: FRED Engineering, 2024.

Road Crashes by Type

On both national and regional levels, a graph illustrating the contribution of various types of crashes to the total number of casualties (Figure 18) enables an understanding of which types of crashes are most critical and thus require priority attention. In these graphs, it is always important to highlight crashes that involved pedestrians, as they usually have a high contribution on the overall fatalities.

Figure 18: Sample Graph of Road Crashes by Type



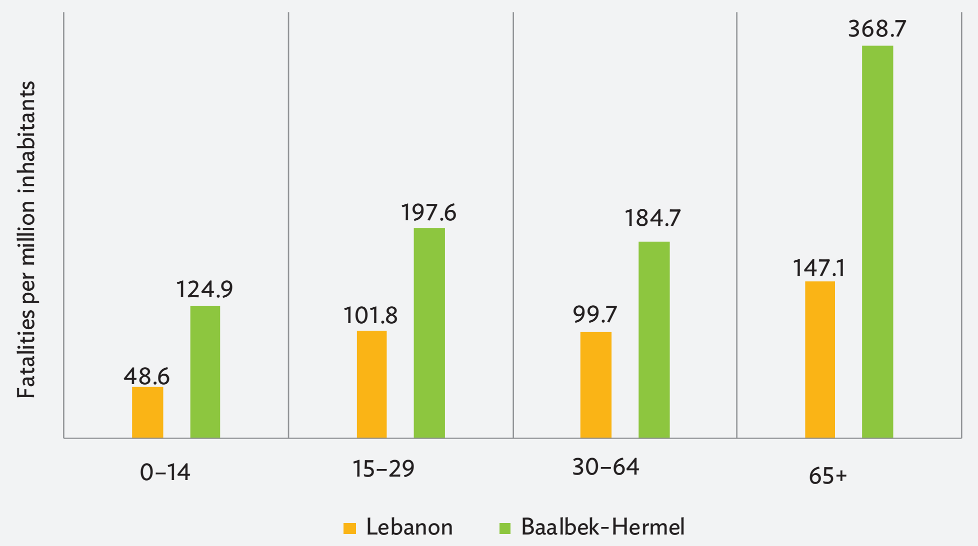
Source: FRED Engineering, 2024.

Road Crashes by Age

Graphs that compare fatality rates by age group (Figure 19) are useful in finding out if there is a particular category that is more prone to fatal road crashes compared with the rest of the population. This comparison can be done along with the national averages to find out if significant variations are present. This type of graph allows for a direct look of the statistics for vulnerable groups, such as children and the older people.

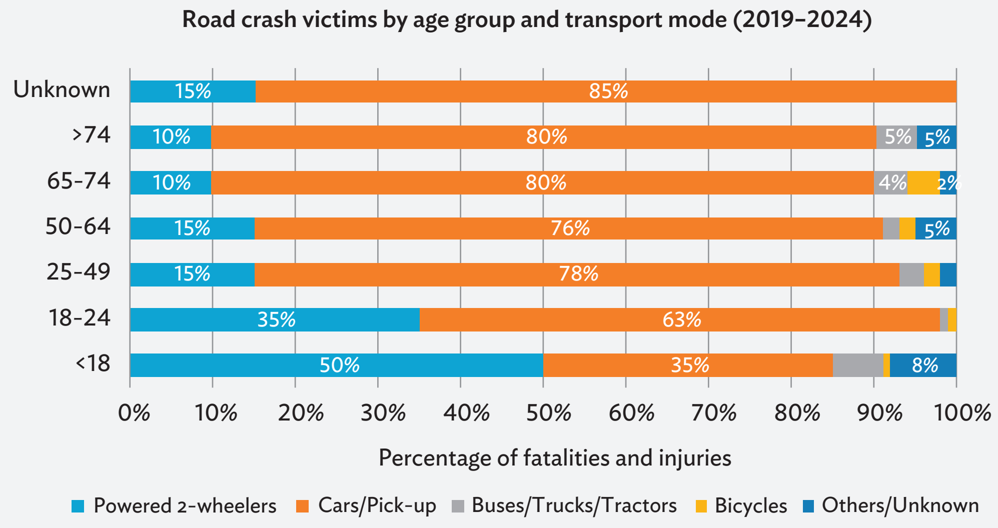
Similarly, a combined graph that correlates data on road crash victims by age group and mode of transport could indicate if there are specific tendencies among groups of users. For example, this type of graph may indicate that road crashes involving two-wheelers are more frequent on younger age groups (under 24 years old), as shown in Figure 20.

Figure 19: Sample Graph of Fatality Rate Comparison by Age Group



Source: FRED Engineering, 2024.

Figure 20: Sample Graph of Road Crash Victims by Age Group and Transport Mode

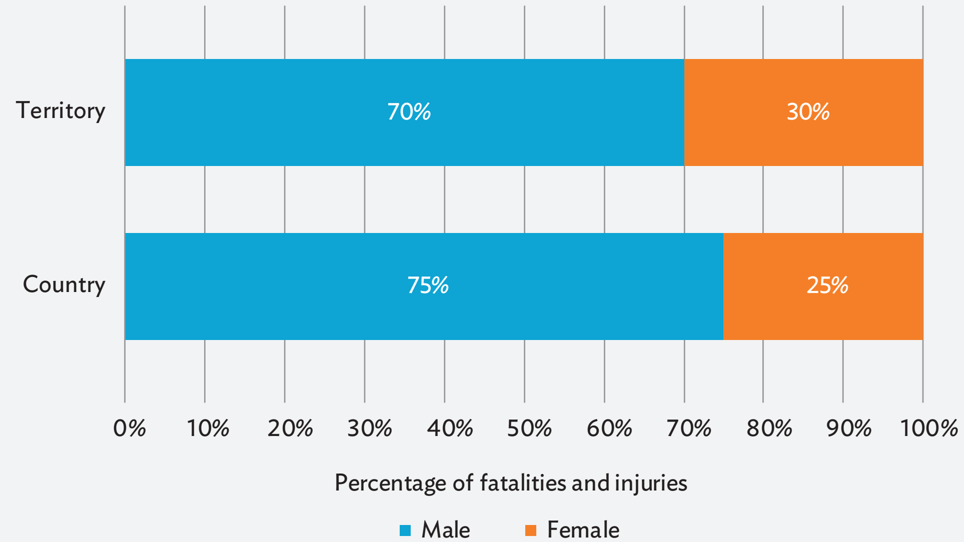


Source: FRED Engineering, 2024.

Road Crashes by Gender

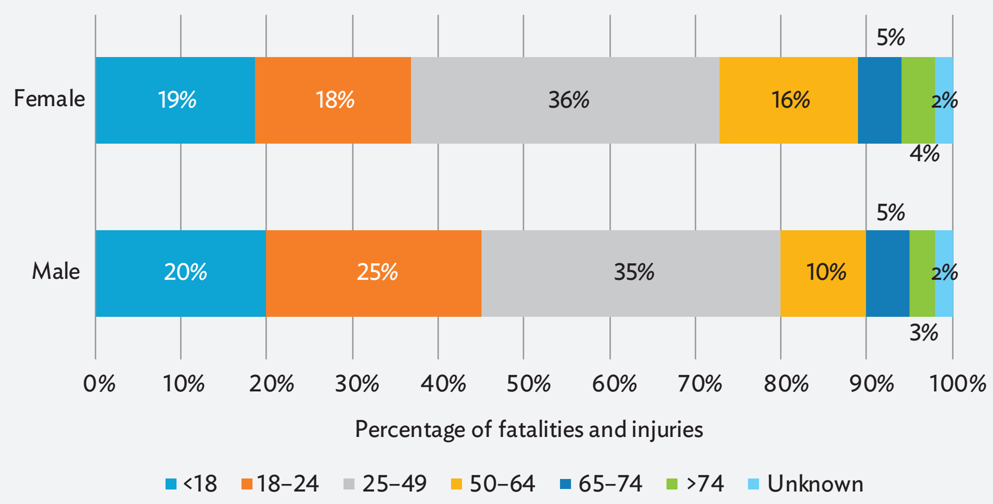
Graphs related to gender can reveal if there are any systemic issues that should be addressed to enhance road safety in a country or in the region overall. A graph that correlates data on road crash victims by gender and by age group would give a good description of how the percentage of fatalities and injuries is distributed among user segments (Figure 21).

Figure 21: Sample Graph of Road Crash Victims by Gender



Source: FRED Engineering, 2024.

Figure 22: Sample Graph of Road Crash Victims by Gender and Age Group

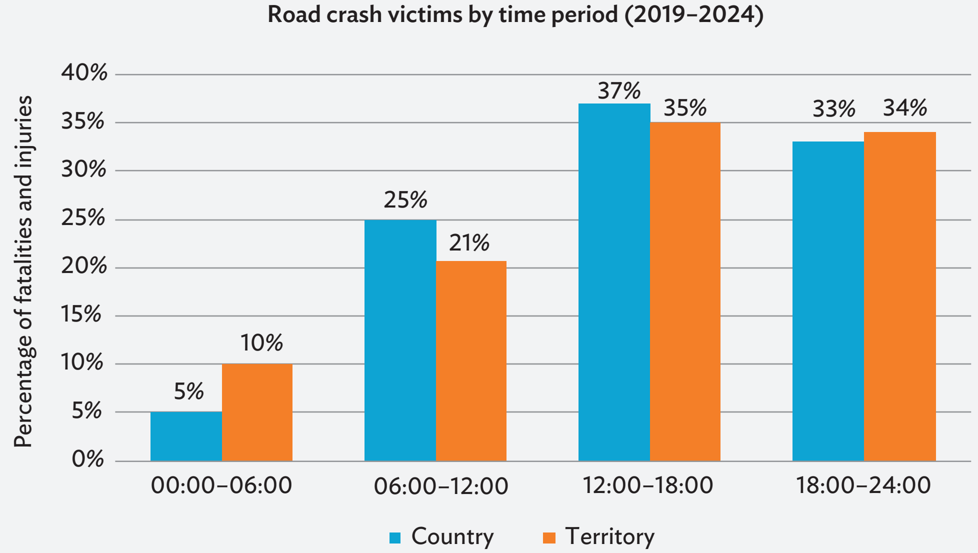


Source: FRED Engineering, 2024.

Road Crash Victims by Time Period

A general graph that correlates data on road crash victims and time period may indicate behavior that leads to road crashes during different hours of the day. In particular, this may indicate the time period when most road crashes happen (Figure 23). For example, a higher number of crashes during the early morning hours (from 12 midnight to 6 a.m.) may indicate systemic issues taking place during this time period that merits further study.

Figure 23: Sample Graph of Road Crash Victims by Time Period



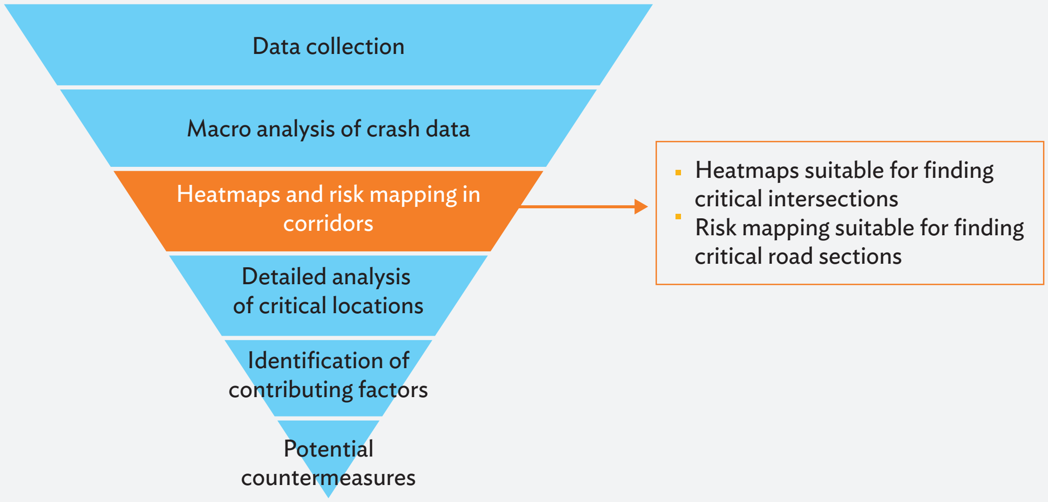
Source: FRED Engineering, 2024.

3.1.2 Heatmaps and Risk Mapping in Corridors

Road crash data analysis, in addition to the macro analysis discussed in previous chapters, must also focus on a detailed analysis of critical locations. To achieve this, two important tools are suitable: heatmaps and risk mapping in corridors.

Heatmaps display the density of crashes over a geographic area, without being constrained by the shape of the road network. Heatmaps use color gradients to represent the intensity of crash events, with hot spots showing the locations where crashes are most frequent. Heatmaps allow for quick visualization of the geographic areas with high crash frequency, thus they are useful for pinpointing critical spots such as intersections, even if they have very different geometries. Instead, the risk mapping accounts for the total of crashes that occurred on each road and allows for categorization according to crash density (e.g., number of crashes per kilometer). Risk mapping also allows easier integration of exposure data, such as traffic data, into the heatmaps. However, risk mapping is constrained by the shape of the roads. Thus, risk mapping can be more suitable for pinpointing critical sections in a road network.

Figure 24: Heatmaps and Risk Mapping



Source: FRED Engineering, 2024.

Risk mapping requires higher precision in the georeferencing of crashes, as any crash located further than a certain set distance (e.g., 25 meters) from the road will be ignored. Risk mapping also gives a more general view of road safety risks, while heatmaps provide a more detailed view of the risks in a determined location. Risk mapping can help determine that a certain road is critical within a road network, while heatmaps can determine critical intersections and even critical points, such as hazardous bends and segments.

It is important to highlight that both tools can be used with either the number of crashes or the number of casualties. Analysis of the injuries and fatalities allows for direct visualization of the places where the crashes have had severe consequences. On the other hand, analysis of the number of crashes allows for an understanding of the risk, as it summarizes the events that could have resulted in severe consequences as well. These analyses, when combined, allow for better understanding of road safety criticalities present in a road network.

Selecting the right GIS software is crucial for heatmaps and risk-mapping activities, as it impacts the efficiency, accuracy, and clarity of the spatial analysis. When selecting the appropriate GIS software in the framework of road safety risk assessment, it is important to consider the license costs, the interface, and the included spatial analysis tools. Regarding license costs, there are available software that are free or open source. On the other hand, user-friendly interfaces are highly recommended, so that it is more approachable for new users performing the crash investigation activities. Ultimately, it is important to ensure that the GIS software has the necessary packages to perform the required spatial analysis, such as the elaboration of buffers, the creation of heatmaps, and operations such as counting the number of crashes inside a road's buffer area.

Heatmaps

The creation of heatmaps is suitable for identifying areas with high concentrations of road crashes (or injuries and fatalities). Heatmaps are usually more suitable for assessing dangerous intersections.

To conduct heatmap analysis, the following steps can be followed using a GIS software:

(1) Import relevant crash (or fatalities and injuries) georeferenced data. A period of at least 5 years of information is recommended.

(2) Add a base map (e.g., OSM or Google Maps) and adjust it to grayscale so the heatmap can be visualized more easily.

(3) Generate the heatmap, possibly through a Kernel Density Estimation method.[8] A radius of 100–150 meters is recommended.

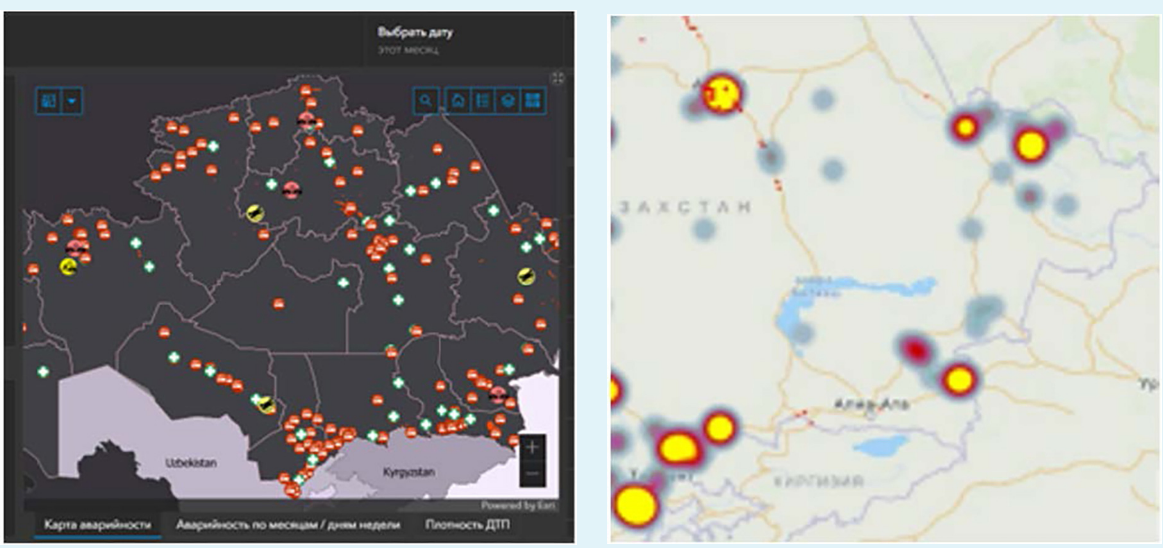
(4) Adjust the symbology to clearly visualize hot spots.

The hotspot analysis allows for summarizing the initial collected information from the number of crashes, or the number of casualties, which otherwise would be difficult to understand visually when represented altogether in a map. As shown in Figure 25, the information on injuries and fatalities can be transformed into a heatmap that allows for quick identification of the most critical intersections within a city.

Box 11: Road Crash Concentration Map in Kazakhstan

The Ministry of Internal Affairs open portal in Kazakhstan includes real-time data and maps where road crashes can be visualized.

Other maps are maintained by the general prosecutor which, based on data received from the traffic police, depict the concentration of road crashes along Kazakhstan's road network.



Source: Government of Kazakhstan, Ministry of Internal Affairs.

8 M. de Smith, F. Goodchild, and P. Longley. 2007. *Geospatial Analysis*. The Winchelsea Press.

Figure 25: Sample Hot Spots Mapping for Injury and Fatality Data in Medellín, Colombia (2017–2022)

Source: FRED Engineering, 2023.

Risk Mapping

Risk mapping is a suitable tool to determine the most critical corridors within a road network, using as base information the georeferenced data from road crashes or from injuries and fatalities.

To conduct a risk-mapping analysis for the corridors, the following steps can be followed using a GIS software:

(1) Import the road network of interest.
(2) "Clean" the network of irrelevant road functional classes for the risk analysis of main corridors (e.g., cycleways, footways, and very small links).
(3) Combine road segments by functional class and name of the road. This will avoid the frequent presence of small segments in the final results.
(4) Split the roads by a standard maximum length (e.g., 5,000 meters) to create uniform road segments. This allows for a better visualization for the crash mapping.
(5) Import relevant crash (or fatalities and injuries) georeferenced data. A period of at least 5 years of information is recommended.
(6) Generate a buffer (e.g., 25 meters) around the road segments to make room for slight errors in the georeferencing of crashes.
(7) Count the number of crashes (or casualties) inside the buffer of each road segment.
(8) Associate the buffer count with each corresponding road segment.
(9) Calculate crashes per kilometer (or victims per kilometer) on each road segment.
(10) Adjust the symbology to categorize the roads according to crash risk. The categorization can be done through percentiles.

Figure 26 presents an example of how the georeferenced crash information can be used to build an adequate risk mapping of the main corridors of the network, with the scope of identifying the most critical road sections.

Figure 26: Sample Risk Mapping of Crash Data in Keserwan-Jbeil, Lebanon (2018–2022)

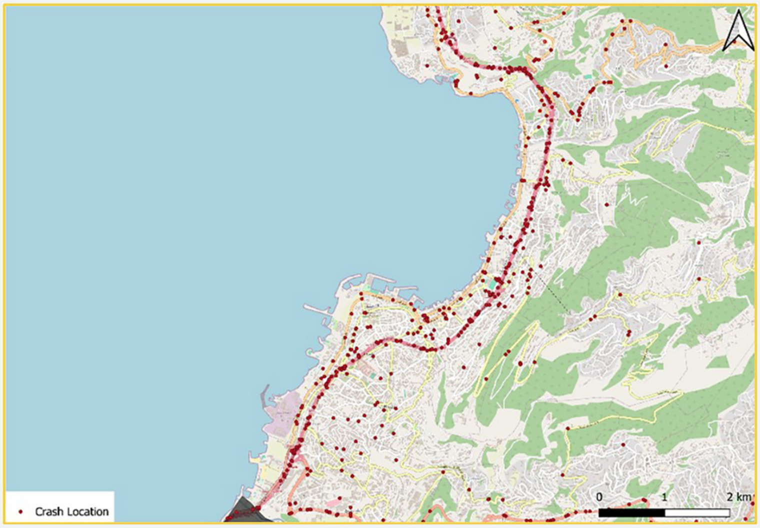


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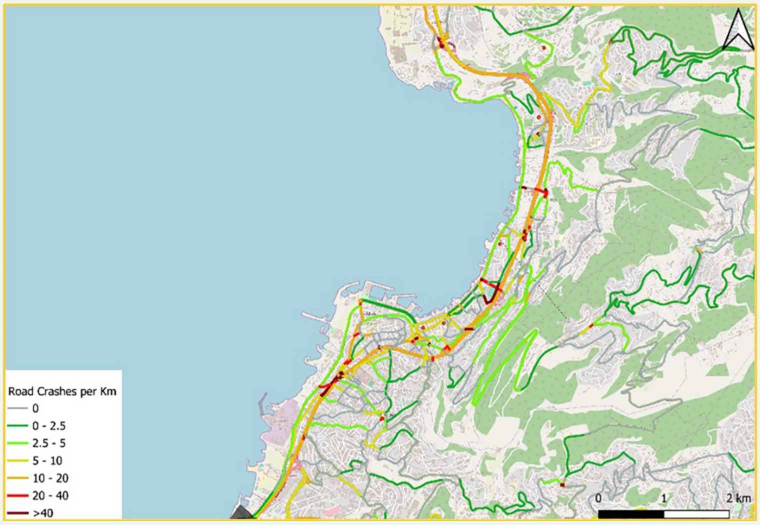
Figure 26 *continued*

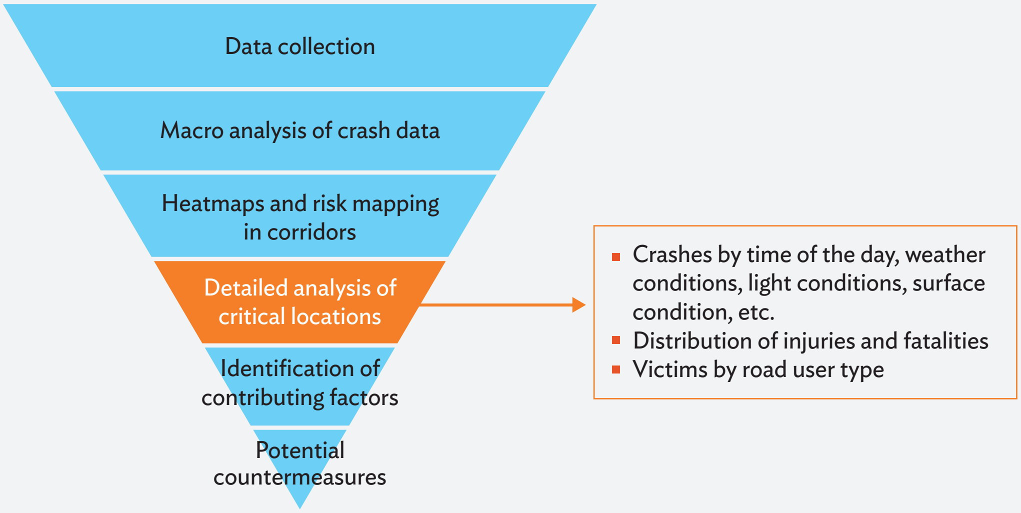


Source: FRED Engineering, 2024.

3.1.3 Detailed Analysis of Critical Locations

After identifying the most critical road sections or intersections, it is often necessary to provide a more detailed analysis for the crash investigation procedures, with the scope of providing a strong ground for the successive identification of contributing factors and selection of potential countermeasures. Some of the graphs used for the macro analysis of crash data can be utilized as well in the detailed analysis of critical sites, such as the graphs related to road crashes by transport mode, by type, and by time of day.

Figure 27: Detailed Analysis of Critical Locations



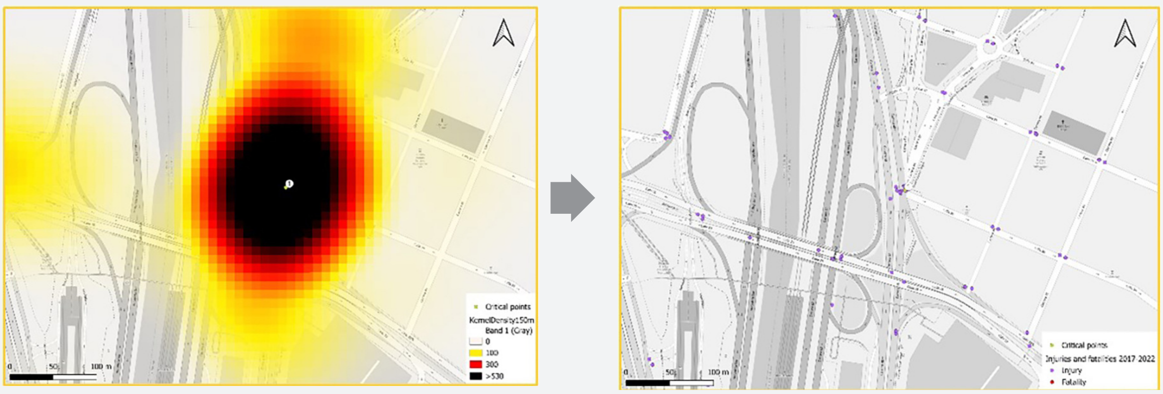
Source: FRED Engineering.

Some examples of crash data analysis identifying contributory factors are presented below. These are not intended to be exhaustive. Specific analysis and cross-referencing of data should be decided based on the location being analyzed. It is recommended to assess all possible data analysis to identify relevant trends and challenges (possibly comparing them with reference analysis).

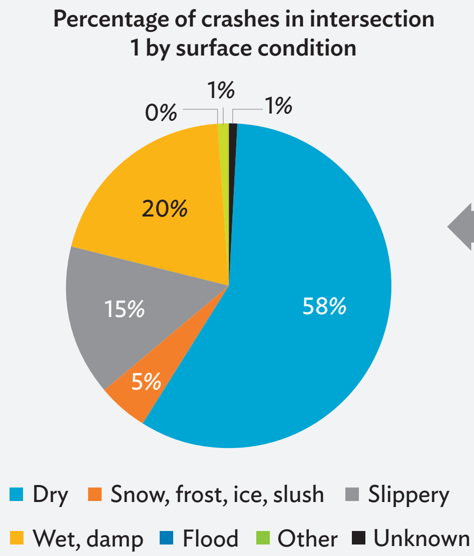
Figure 28 summarizes four steps in conducting a detailed analysis of a critical intersection:

(1) Locate one of the hot spots that resulted from the heatmap procedure.
(2) Perform a spatial selection of the crashes (or fatalities and injuries) related to the hotspot.
(3) Extract the table of attributes from those events.
(4) Perform the detailed analysis graphs from the extracted information of the critical intersection.

Figure 28: Sample Procedure for the Analysis of a Critical Intersection



Crash ID	Year	Lat	Long	Severity	Surface condition
1001	2021	X1	Y1	Injury	Dry
1002	2022	X2	Y2	Fatality	Dry
1003	2024	X3	Y3	Injury	Slippery
1004	2022	X4	Y4	Injury	Dry
1005	2019	X5	Y5	Fatality	Slippery
1006	2021	X6	Y6	Injury	Wet, damp
1007	2021	X7	Y7	Injury	Dry
1009	2023	X8	Y8	Fatality	Wet, damp



Source: FRED Engineering, 2024

Figure 29 summarizes four steps in conducting a detailed analysis of a critical road section:

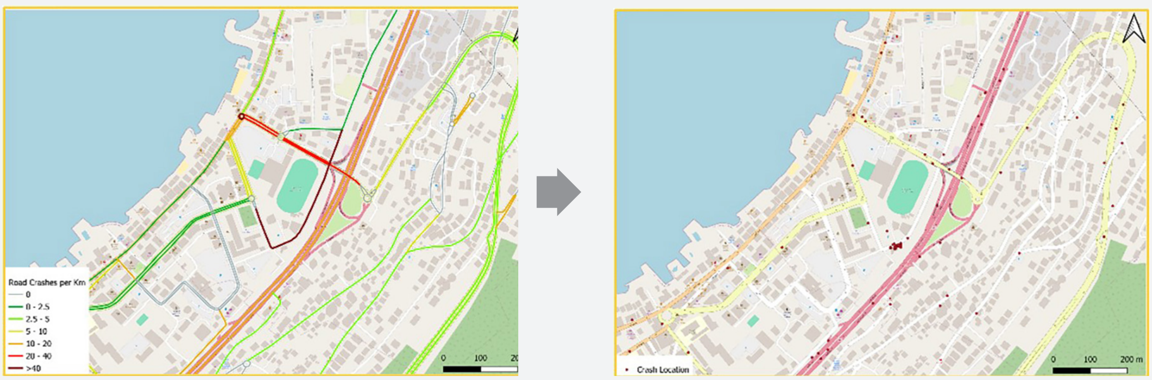
(1) Locate one of the most critical road segments that resulted from the risk-mapping procedure. This can be done through sorting the table of attributes by crash per kilometer value.

(2) Perform a spatial selection of the crashes (or fatalities and injuries) related to the critical corridor.

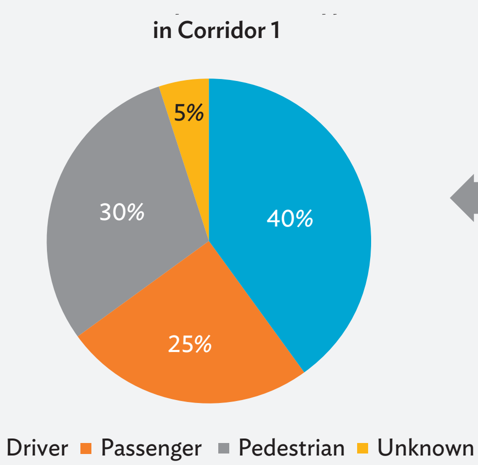
(3) Extract the table of attributes from those events.

(4) Perform the detailed analysis graphs from the extracted information of the critical location.

Figure 29: Sample Procedure for the Analysis of a Critical Corridor



Crash ID	Year	Lat	Long	Fat.	Inj.	Road User Type
1001	2024	X1	Y1	1	2	Driver
1002	2024	X2	Y2	0	0	Passenger
1003	2023	X3	Y3	0	1	Pedestrian
1004	2022	X4	Y4	2	1	Passenger
1005	2019	X5	Y5	0	0	Passenger
1006	2021	X6	Y6	0	2	Pedestrian
1007	2024	X7	Y7	1	3	Driver
1009	2023	X8	Y8	3	4	Pedestrian

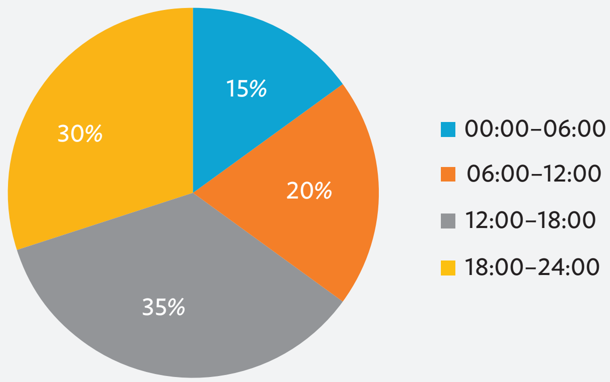


Source: FRED Engineering, 2024

Crashes by Time of the Day

Analyzing crashes by time of the day in a critical location (Figure 30) allows for the identification of high-risk periods when crashes are likely to occur. This information would indicate specific contributing factors that more prevalent during certain periods, such as driver fatigue during late-night hours or congestion-related crashes during traffic rush hours.

Figure 30: Sample Analysis of a Critical Location: Crashes by Time of the Day

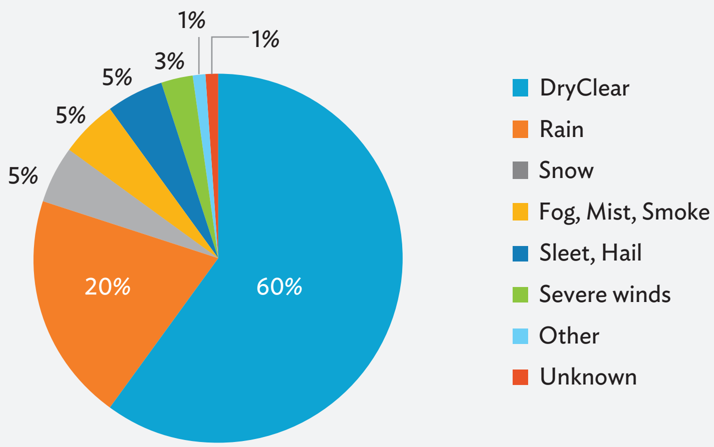


Source: FRED Engineering, 2024.

Crashes by Weather Conditions

A graph that correlates crashes and weather conditions (Figure 31) takes into account adverse weather conditions such as rain, snow, or fog contributing to crash risk. Moreover, analyzing crashes by weather conditions allows for the identification of specific hazards, such as reduced visibility or decreased traction on slippery roads.

Figure 31: Sample Analysis of a Critical Location—Crashes by Weather Conditions

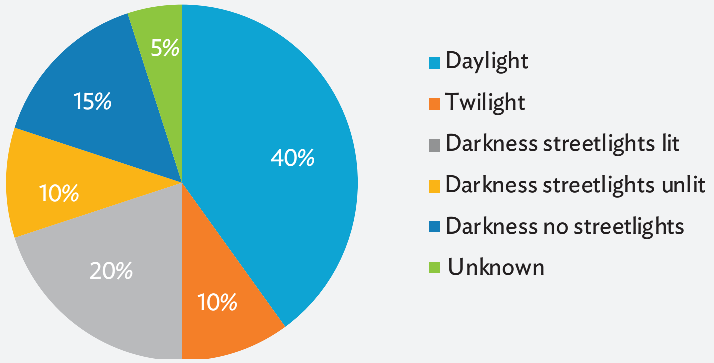


Source: FRED Engineering, 2024.

Crashes by Lighting Conditions

Analyzing crashes by lighting conditions in a critical location (Figure 32), including the presence or absence of streetlights, could identify patterns, trends, and high-risk conditions that make crashes more prevalent. The analysis provides insights on strategies to mitigate risks, improve visibility, and enhance road safety in critical ocations.

Figure 32: Sample Analysis of a Critical Location—Crashes by Lighting Conditions

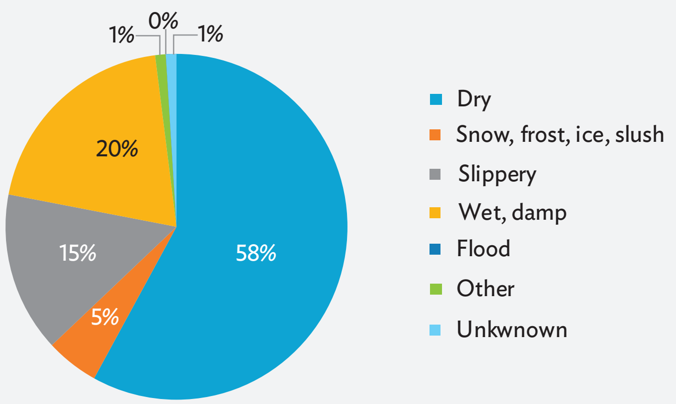


Source: FRED Engineering, 2024.

Crashes by Surface Condition

Surface conditions, including wet roads, icy patches, or slippery surfaces, significantly impact vehicle traction, thus influencing the likelihood of crashes. By examining crash data in relation to the surface condition (Figure 33), an identification of systemic issues is possible, such as the presence of inadequate drainage systems or deteriorated road infrastructure. Such findings can be valuable when proposing interventions such as regular maintenance to repair potholes or the application of anti-skid treatments in slippery sections.

Figure 33: Sample Analysis of a Critical Location—Crashes by Surface Condition

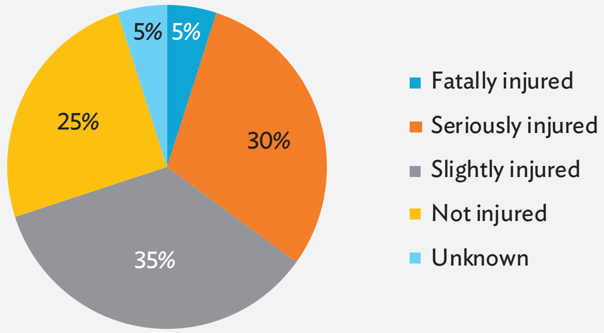


Source: FRED Engineering, 2024.

Distribution of Injuries and Fatalities

By analyzing the distribution of injuries and fatalities (Figure 34), it is possible to gain insight into the severity of previous crashes in a critical location. This can contribute to crash investigation procedures by revealing high-risk areas and possible conflicts with vulnerable road users. This can also highlight the need for interventions in a critical location to reduce crash severity.

Figure 34: Sample Analysis of a Critical Location—Distribution of Injuries and Fatalities

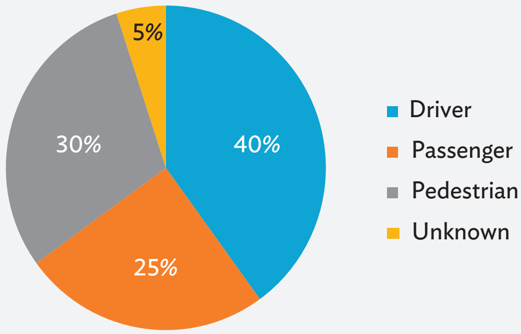


Source: FRED Engineering, 2024.

Victims by Road User Type

Analyzing crash victims by road user type in a critical location (Figure 35) gathers important insights to understand the contributing factors and developing targeted interventions to improve road safety for all users. For instance, a high percentage of pedestrian victims may highlight the need for improved infrastructure, such as safe pedestrian crossings or road signals. This can be correlated with the distribution of crash casualties to observe with more detail which type of road users have a higher contribution to the fatalities, and which have a higher contribution to overall serious injuries.

Figure 35: Sample Analysis of a Critical Location—Victims by Road User Type

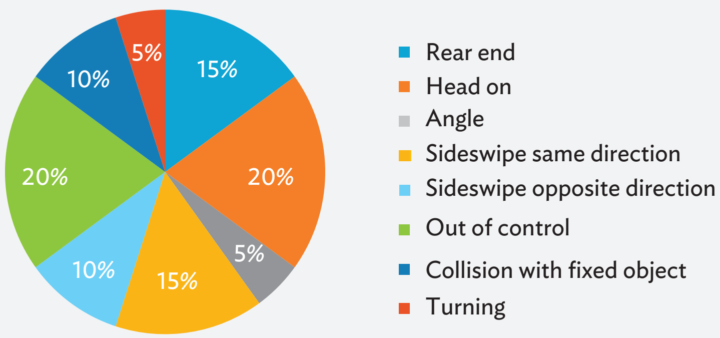


Source: FRED Engineering, 2024.

Events by Collision Type

Analyzing road crashes by collision type is fundamental for understanding the specific dynamics and circumstances leading to crashes in a critical location (Figure 36). Each collision type is associated with a specific risk factor and requires tailored countermeasures. For instance, the prevalence of head-on crashes could reveal the need for median barriers or central rumble strips to avoid errant vehicles invading opposing lanes. This can be correlated with the distribution of casualties to study how different collision types contribute to the overall fatalities and severe injuries in a critical location.

Figure 36: Sample Analysis of a Critical Location—Events by Collision Type



Source: FRED Engineering, 2024.

3.2 Selection of Countermeasures for a Critical Location

The following step in the crash investigation process relates to selecting countermeasures based on identified challenges and contributing factors. A countermeasure refers to a strategy implemented aimed at decreasing crash frequency and/or severity. Before selecting interventions, an analysis of road crash and casualty data is conducted (as outlined in the previous section) to assess the unique characteristics of each critical site and pinpoint recurring crash types or patterns.

This section involves a deeper evaluation of critical sites to identify factors that potentially contribute to the types of crash observed and the patterns of road crashes. Once contributing factors are identified, appropriate countermeasures are selected.

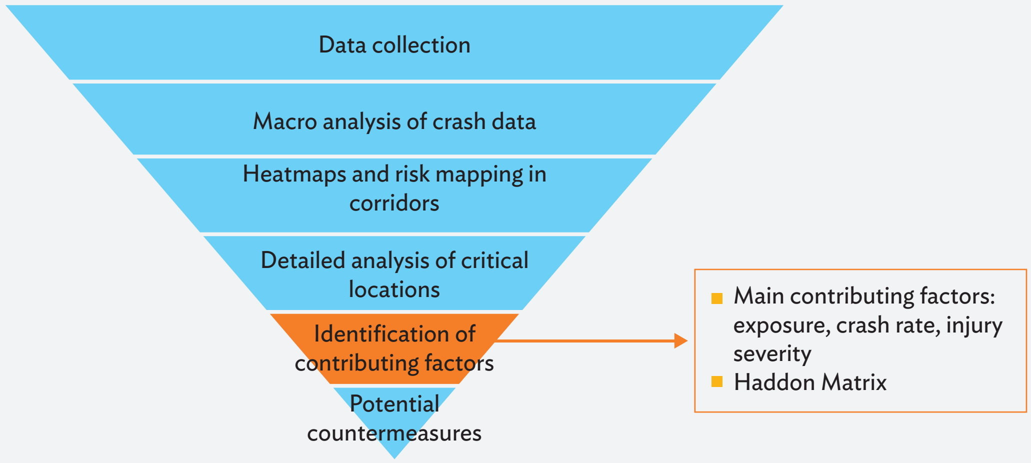
3.2.1 Identification of Contributing Factors

The number of fatalities and injuries relates to three main factors that contribute to road crashes:[9]

- **Exposure** refers to the level of activity during which crashes can take place. In the context of road traffic, the amount of activity is related to the amount of travel, which is measured in kilometers traveled. The various modes of travel on roads (e.g., driving a car, using public transportation, walking, or cycling) carry different levels of crash risk. Therefore, the choice of travel mode may affect the number of crash casualties.

[9] G. Nilsson. The three dimensions of exposure, risk, and consequence. Unpublished.

Figure 37: Identification of Contributing Factors



Source: FRED Engineering.

- **Crash rate** represents the likelihood of a crash per exposure unit, which indicates the likelihood of a crash occurring. The probability of crashes is influenced by numerous risk factors associated with components of the traffic system, including infrastructure, traffic control devices, vehicles, and road users. A risk factor for crashes encompasses any element that heightens the likelihood of crash occurrences. In principle, risk factors are statistically linked to crash probabilities; however, not all risk factors can be deemed direct causes of crashes.
- **Injury severity** denotes the consequences of crashes concerning injuries to people or damage to property. Official road crash data in numerous countries categorize crashes by severity based on a basic scale, including fatal crashes, serious injury crashes, minor injury crashes, and property damage crashes.

The outcome of a crash, whether in terms of injury to individuals or property damage, is also influenced by a multitude of factors related to the same components of the traffic system as those associated with crash risk factors.

According to the three main contributing factors to road crashes, there are four methods for diminishing the number of casualties:[10]

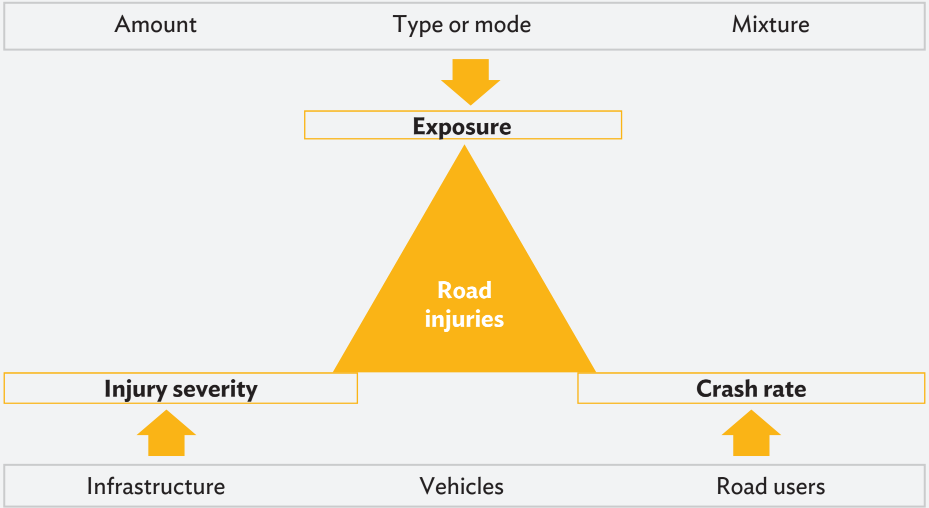
- By diminishing crash risk exposure, i.e., by decreasing the amount of travel.
- By shifting travel to transportation modes with lower levels of risk.
- By decreasing the crash rate for a specific amount of travel.
- By decreasing the severity of road crashes, i.e., protecting people from injuries more effectively.

Figure 38 shows the taxonomy of major factors affecting road safety. It represents the correlation between the injury severity factor, the crash rate factor, and the exposure factor.

This manual does not attempt to comprehensively cover all known contributing factors to road crashes. Instead, the focus is narrowed to highlight some of the key factors identified as significant contributors to crash risks.

[10] R. Elvik. 2009. *The Handbook of Road Safety Measures*. 2nd ed.

Figure 38: Taxonomy of Factors Affecting Road Safety



Source: R. Elvik. 2009. *The Handbook of Road Safety Measures.* 2nd ed.

The results from the diagnosis of data and variables are the starting point for the identification of the contributing factors. It is important to highlight that multiple contributing factors may be identified for a certain crash type or pattern. Thus, the aim of this step is to list all the possible contributing factors for the previously identified crash types or patterns. Once a comprehensive list of factors that contribute to the occurrence of road crashes has been obtained, engineering expertise is used to capture factors that are deemed most crucial for every type or pattern of road crash.

In certain cases, it may be difficult to identify a particular contributing factor, even in the presence of a notable crash type or pattern at the critical location. In such scenarios, necessary assessments can be made to determine the presence of factors affecting the site in question. Also, it can be useful to check for atypical driving behaviors at the critical site.

The Haddon Matrix is an example of methodology serving as a helpful framework for pinpointing crash contributing factors (footnote 4). It categorizes these factors into human, vehicle, and road infrastructure. By relating possible conditions occurring before, during, and after a crash to each category, the matrix aids in identifying the underlying reasons for each identified crash type or pattern.

This matrix can be filled in both during the data collection phase (as described in section 2.1.6) and during the analysis phase (typically by experts in charge of selecting interventions and decision-making). This second phase typically implies a deepening of the information filled in during the first phase, based on crash and other road safety data collected.

Box 12: Example on How to Fill In the Haddon Matrix

Context

The diagnosis of data and variables has revealed a critical road section through the risk mapping tool in corridors. Detailed analysis of the critical location reveals that 180 crashes took place from 2019 to 2024, resulting in 216 injuries and 27 fatalities. After extracting the specific crashes for this critical location, the analysis indicates the most frequent crash types and patterns, with the run-off-road crash type as the most common one (62% of crashes).

The analysis reveals that in 33% of the crashes, the driver or rider was distracted by use of electronic devices; in 52%, driver or rider was not using safety equipment, and 15%, the driver or rider tested positive for alcohol. By road user type, majority of the crash victims were drivers or riders (85%), and the rest are passengers (10%) and pedestrians (5%). In most cases, the crashes involved motorcycles (55%) and cars (30%). By gender, 65% of the crash victims were male and 35% were female, with the predominant age group 15–29 years (35%) and 30–64 years (30%). Most of the crashes (45%) occurred in the time period 12 noon to 6 p.m. (daylight). The analysis also reveals that on 35% of the crash events, the surface condition was wet or damp, and on 33% the technical inspection of the vehicles was not met.

The road section is a single two-way rural carriageway, with one lane per direction. The lane width is 2.75 meters, no shoulders are present, and the pavement is inadequately maintained. The visibility in the road is limited due to the presence of vegetation and the slope of the road is 8%.

Investigation

With the results of the detailed analysis for the critical location, a Haddon Matrix is filled for each one of the identified most relevant crash type or pattern.

Table: Sample Haddon Matrix for Run-Off-Road Crash Type

Phase of the Road Crash	Human-Related Factors	Vehicle-Related Factors	Infrastructure-Related Factors
Before the occurrence of the crash (event or feature that determines the hazardous situation)	cell phone use, alcohol drinking, distraction	lack of vehicle maintenance, worn out tires, worn out brakes	inadequate lane width, inadequate roadway shoulders, inadequate maintenance, poor visibility
During the crash (event or feature that determines the severity of the crash)	failure to wear a seat belt, failure to wear PPE, injury vulnerability, age	type of vehicle, heights of bumpers and absorption of energy, design of headrests, operation of airbags	grade, surface friction
After the occurrence of the crash (crash outcome factors)	age, gender	ease of removing injured passengers	health services time of response, subsequent post-crash care

PPE = personal protective equipment.

Source: Developed by FRED Engineering based on American Association of State Highway Transportation Officials. 2009. *Highway Safety Manual*. 1st edition.

A crucial category of contributing factors addressed within the Haddon Matrix pertains to human factors, which provide insights into how human behavior contributes to the incidence of crashes. This helps in developing interventions that interrupt the causes of road crash. Factors such as fatigue, distraction, or driving while under the influence of alcohol or drugs should be carefully considered in this context.

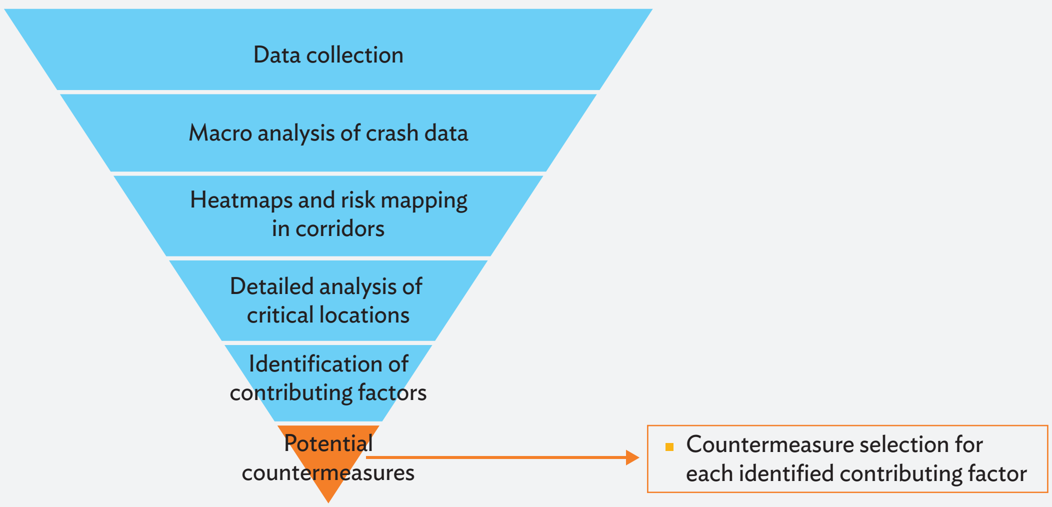
The Haddon Matrix should be filled in with contributing factors that arise from the diagnosis process, to ensure that the conclusions drawn are data driven. Thus, the matrix may include issues that were found on a national or territorial level (i.e., macro analysis of crash data) and could apply to a specific critical location, as well as issues that may arise directly from the detailed analysis of the critical location. Engineering judgment is deemed important in this phase in selecting factors that contribute the most to the occurrence of each road crash type or pattern.

Figure 38 may be included as well in the matrix, given the specific conditions of the critical locations. Appendix 2 contains lists of possible contributing factors that may be included in the construction of the Haddon Matrix, which include factors involving pedestrians and cyclists, along roadway segments, and intersections with and without signals. The lists, however, are not meant to be exhaustive and should be used simply as a guide in filling up the Haddon Matrix.

3.2.2 Potential Countermeasures

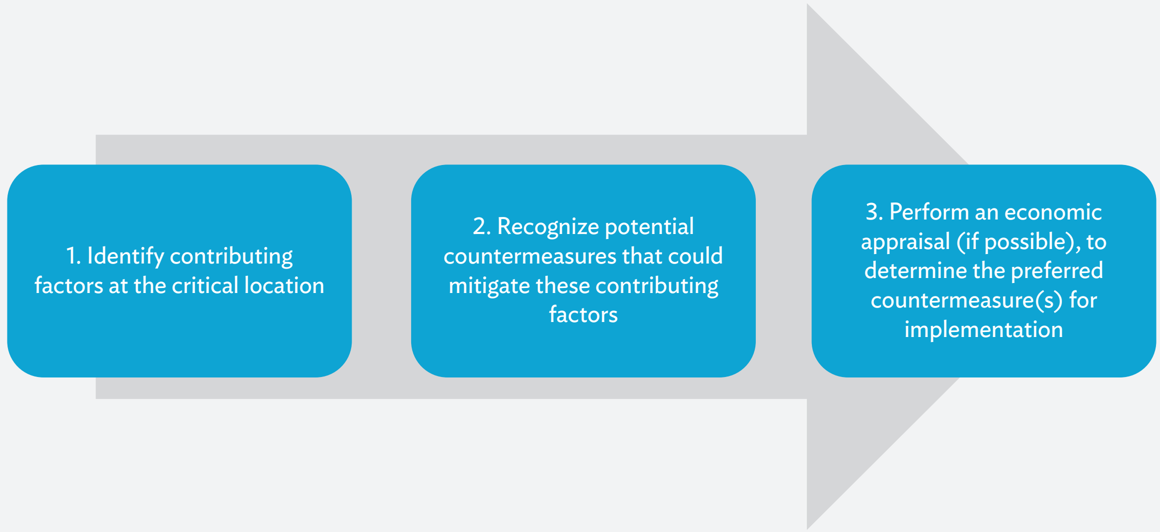
The selection of potential countermeasures proceeds through the summarized steps in Figures 39 and 40.

Figure 39: Potential Countermeasures



Source: FRED Engineering..

Figure 40: Selection of Potential Countermeasures



Source: American Association of State Highway and Transportation Officials. 2010. *Highway Safety Manual*. 1st Ed.

After identifying contributing factors, specific countermeasures can be pulled out to address each of them, which requires the application of engineering expertise and familiarity with local conditions. In this sense, it is required to understand why the given contributing factors are occurring in a determined location and what is physically and financially possible to deal with them. Multiple countermeasures can be proposed for a single contributing factor.

Generally, potential countermeasures target either infrastructure, vehicles, or road users. These elements, as outlined in the taxonomy of factors impacting road safety (Figure 38), play a significant role in influencing both injury severity and crash rates.

In the literature, some significant documents and websites can be used to identify the potential countermeasures that could mitigate previously recognized contributing factors. Some documents assign a qualitative score on the level of effectiveness of the countermeasure according to past experiences, while others specify the crash modification factors (i.e., the expected modification in road safety conditions following the implementation of an intervention). The modification factors allow for a quantitative evaluation of the expected improvement that a specific countermeasure would have on the number of crashes after its implementation. Possible sources that can be used to find countermeasures related to each one of the identified crash risks and patterns or concerns are presented in Table 11.

Table 11: Sources for Countermeasures

Document/Website	Source	Description
The Handbook of Road Safety Measures	Elvik, R. (2009)	Groups road safety measures into 10 different categories: • Road design and road equipment • Road maintenance • Traffic control • Vehicle design and protective devices • Vehicle and garage inspection • Driver training and regulation of professional drivers • Public education and information • Police enforcement and sanctions • Post-accident care • General purpose policy instruments
Highway Safety Manual	American Association of State Highway and Transportation Officials (AASHTO) (2009)	Includes countermeasures and crash modification factors related to roadway segments in the following categories: • Roadway elements • Roadside elements • Alignment elements • Roadway signs • Roadway delineation • Rumble strips • Traffic calming • On-street parking • Roadway treatments for pedestrians and bicyclists • Highway lighting • Roadway access management • Weather issues Also includes countermeasures and accident modification factors related to Intersections in the following categories: • Types of intersections • Management of accesses • Design elements of intersections • Traffic control elements at intersections
Road Safety Toolkit	International Road Assessment Programme (iRAP) (2022)	Includes information about treatments related to safer people, roads, and vehicles. Safer People section includes topics such as the following: • Safe speed • Dealing with alcohol and other drugs • Initiatives for children's safety • Education • Medical response to emergencies • Management of fatigue • Protective devices such as helmets • Driving licenses • Publicity • Restraint devices

continued on next page

Table 11 *continued*

Document/Website	Source	Description
		Safer Road section includes the following topics: • Intersections • Midblock • Roadsides • Vulnerable road users • Speed management and traffic calming Safer Vehicle section includes the following topics: • Regulations for motor vehicles • New car assessment programs • Safety devices • Safety assessment of used cars • Technical inspection of the vehicles
FHWA Highway Safety Programs. Proven Safety Countermeasures	Federal Highway Administration (FHWA) (2024)	Includes a collection of 28 countermeasures and strategies organized by the focus area that they address: • Speed management • Pedestrian/bicyclist • Roadway departure • Intersections • Crosscutting (more than one focus area)
European Road Safety Decision Support System	SafetyCube DSS (2016)	Includes measures related to the following topics: • Behavior (e.g., law and enforcement, awareness raising and campaigns) • Infrastructure (e.g., road surface treatments, road markings at junctions) • Vehicle (e.g., driver assistance) • Post-impact care (e.g., prehospital medical care, ambulances/helicopters)
Countermeasures That Work: A Highway Safety Countermeasure Guide For State Highway Safety Offices	National Highway Traffic Safety Administration. (2018)	Includes effective, evidence-based countermeasures for traffic safety problem areas such as the following: • Alcohol- and drug-impaired driving • Seat belts and child restraints • Speeding and speed management • Distracted and drowsy driving • Motorcycle safety • Young drivers • Older drivers • Pedestrian safety • Bicycle safety

Source: FRED Engineering.

After the selection of countermeasures, an appraisal may be performed to determine the preferred countermeasure(s) for implementation based on estimated economic benefits or in terms of effectivity. Nevertheless, this task is challenging and may, in some instances, not be possible due to the lack of information regarding the crash modification factors associated with a particular countermeasure, or difficulties in estimating the costs of the countermeasure.

In cases where it is possible, it provides a strong framework for the selection of the preferred countermeasure(s). The economic appraisal may be done through a cost–benefit or cost-effectiveness analysis.

Both approaches start by estimating the benefits achievable from the implementation of a given project (i.e., a set of interventions), which are typically represented as the expected crash frequency or severity variation resulting from the implementation of a countermeasure.

To assign an economic value to the benefits, it is necessary to determine the monetary equivalent of a crash. This can be done by first estimating a value for the fatalities and for the serious injuries through the gross domestic product per capita of the country. Some methodologies, such as iRAP, suggest a value of a fatality equivalent to 70 times the gross domestic product per capita, and a value for a serious injury equivalent to 25% of the value of a fatality.[11] Then, the value of a crash can be determined considering the average number of casualties that took place per crash, according to the historical data.

The cost–benefit analysis can be performed via the net present value (NPV) or the benefit–cost ratio (BCR). The method for performing the NPV analysis is as follows (Footnote 4):

(1) Estimate the reduction in road crashes resulting from the implementation of the safety countermeasure.
(2) Represent benefits from converting the change in the estimated average of road crash frequency into a monetary value.
(3) Convert annual monetary benefits into a present value.
(4) Calculate the current value of costs associated with the project implementation.
(5) Calculate the NPV by using the following formula:

$$NPV = PV_{Benefits} - PV_{Costs}$$

Where:
$PV_{Benefits}$: *Present value of project benefits*
PV_{Costs}: *Present value of project costs*

(6) If the NPV is higher than 0, the individual project is economically justified. The preferred countermeasure is the one with the highest NPV.

The method for performing the BCR is as follows (Footnote 4):

(1) Calculate the current value of the estimated change in the average of road crash frequency.
(2) Determine the current value of the costs associated with the safety improvement project.
(3) Evaluate the BCR by using the formula:

$$BCR = \frac{PV_{Benefits}}{PV_{Costs}}$$

Where:
$PV_{Benefits}$: *Present value of project benefits*
PV_{Costs}: *Present value of project costs*

(4) If the BCR exceeds 1, then the project is economically warranted. The preferred countermeasure is the one with the highest BCR.

[11] International Road Assessment Programme (iRAP). 2023. *iRAP Star Rating and Investment Plan Manual Version 1.4*.

The expected change in the average road crash frequency is not quantified in monetary terms by the analysis of cost-effectiveness, which instead compares it directly with the countermeasure costs. This method can be used when monetizing the benefits is not possible (e.g., due to lack of information on the social costs of road crashes). It is expressed as the annual cost per crash reduced. The method for performing the cost-effectiveness analysis is as follows (Footnote 4):

(1) Estimate the variation on the average crash frequency resulting from the safety improvement project.

(2) Calculate the project costs.

(3) Determine the cost-effectiveness of the project aimed at improving site safety by using the following formula:

$$Cost — Effectivenes\ Index = \frac{PV_{Costs}}{N_{Predicted} — N_{Observed}}$$

Where:

PV_{Costs}: *Present value of project costs*

$PV_{Predicted}$: *Predicted crash frequency for year y*

$PV_{Obeerved}$: *Observed crash frequency for year y*

(4) The preferred countermeasure is the one with the lowest cost-effectiveness index.

4 Reporting and Presentation

To identify possible actions aimed at improving road safety, reliable and clear reports based on the systematic analysis of road crashes and other road safety data should be developed.

Reports should use different types of data. For example, crash and casualty data may only be represented through numbers, although it is more effective to develop data over time, or compare, in different situations, crash rates per population, number of registered vehicles, and other indicators. Using data on crash location, a correlation between road crashes and infrastructure features can be established.

4.1 Developing Clear and Concise Reports and Presenting Data Efficiently

Crash and casualty data should enable the various actors involved in road safety issues to carry out activities effectively. For example, the police may use the data to figure out how to implement control activities.

Based on various considerations made throughout this manual, a report structure is proposed in Table 12.

Table 12: Proposed Report Structure

Chapters	Topics

Macro analysis of crash data	• National and regional trends in the number of road crashes and crash casualties
	• Regional comparisons of trends
	• Analysis of road crashes by
	  ° Mode of transport
	  ° Type of crash
	  ° Age and gender
	  ° Time period

Heatmaps and risk mapping	• Creation of heatmaps to identify the most critical intersections within the road network • Creation of risk maps to determine the most critical corridors of the road network

continued on next page

Table 12 continued

Chapters	Topics

Analysis of critical locations	• Location of high crash risk sites/segments resulting from the heatmap/risk mapping procedure
	• Spatial selection of crashes related to these sites/segments
	• Extraction of a table of attributes from these crash events
	• From the extracted information of the critical location, processing of analytical graphs relating to road crashes by
	  ◦ Time of day
	  ◦ Weather conditions
	  ◦ Light conditions
	  ◦ Surface conditions
	  ◦ Road user type
	  ◦ Collision type

Analysis of other road safety data	• Risk exposure data
	  ◦ Traffic estimates
	  ◦ Person at risk estimates
	• Safety performance indicators
	  ◦ Infrastructure-related
	  ◦ Vehicle-related
	  ◦ Road users-related

Identification of contributing factors	• Identification of factors related to human behavior, vehicles, and infrastructure that determine crashes
Definition of potential countermeasures	• Determining the countermeasures to be taken for each identified contributing factor
Determination of the benefits that can be obtained from the countermeasures adopted	• Evaluation of the results achieved in terms of road crash and crash casualty reduction (e.g., through the CMFs) • Economic analysis of the application of selected countermeasures (e.g., cost–benefit estimation).

CMFs = crash modification factors
Source: FRED Engineering.

An example on how a report based on the analysis of crash data can be structured is provided by the Road Safety Annual Report prepared by the International Transport Forum.[12]

4.2 Communicating Findings to Stakeholders

All entities responsible for collecting and using road safety data should be informed on the results of the reports so that each stakeholder, in line with its competencies and resources, can take the most appropriate actions to ensure the reduction of traffic casualties and, in general, the improvement of road safety.

For this purpose, periodic interministerial or interagency meetings are recommended, ideally coordinated by the country lead agency. Table 13 lists the main activities that the different entities should carry out based on challenges that emerged from the reports and observations made during the various meetings.

12 International Transport Forum. *Road Safety Annual Report 2023*.

Table 13: Activities Carried Out by the Main Agencies Involved in Road Safety

Entity	Main Activities
Government departments	• Play the role of lead agency for the management of road safety • Aggregation of all available road safety data and correction of any anomalies • Implementation of road safety strategies • Definition of high crash risk locations • Definition of the road design • Promotion of road safety campaigns
Police	• Enforcement of measures related to road safety • Training on the use of the crash collection forms
Medical facilities	• Post-crash care • Collaboration with the police to enhance the collection of crash and casualty data • Determination of injury severity • Updating the national crash database
Statistics offices	• Checking, correcting, augmenting data collected from other sources (e.g., police, hospitals)
Insurance companies	• Construction of traffic indicators

Source: FRED Engineering.

4.3 Training and Refresher Courses

Training and capacity-building initiatives, including refresher courses, need to be organized at a regional level so that stakeholders in different countries adopt standardized procedures for the collection and management of road safety data. These initiatives must involve agencies in charge of crash data collection (i.e., police officers and medical personnel) and national agencies in charge of analyzing, reporting, and communicating road safety results.

The topics to be covered during these courses are listed in Table 14.

Table 14: Topics to Be Addressed in Training and Capacity-Building Initiatives

Entity	Topics to be Addressed
Police	
Traffic police units	• Gathering information from witnesses of the road crash • Use of devices for conducting alcohol tests • Use of electronic devices for collecting road crash data • Transfer of data to the national database
Police department	• Control of data received from traffic police units to avoid underreporting of data • Use of the data stored in the national database to conduct concise and reliable crash and road safety analysis
Hospitals	
Medical personnel at the crash scene	• First aid treatment of victims
Medical facilities	• Hospitalization of victims • Gathering information on the conditions of victims • Recording injury and trauma data in the national database so that the information collected can be merged with that collected by the police • Use of data to produce concise and reliable injury trends

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Table 14 continued

Entity	Topics to be Addressed
Road safety agency in charge of data analysis and reporting	
Road safety agencies, statistics offices, government departments	• How to use the common database and information system to access, manage, and analyze road safety data • Best practices for data analysis • Framework for creating harmonized and comparable reports at the regional level, while also tailoring them to meet national needs and requirements • How to communicate results and advocate for informed road safety initiatives

Source: FRED Engineering.

4.4 Using Data to Inform Road Safety Initiatives

Reliable and accurate road safety data are important for planning effective road safety policies and monitoring performance.

Advertising campaigns are an important tool for improving road safety results. These can be used to do the following:

- Raise public awareness of road safety issues.
- Increase awareness of penalties for traffic violations.
- Contribute to changing people's attitudes toward road safety issues.

Effective advertising campaigns require careful thought and planning. Advertising campaigns alone will probably not convince road users to change their behavior. It is also necessary to educate people to understand why they should change. Road safety education should be delivered in different settings such as schools, universities, sports clubs, and workplaces.

Road safety education can be delivered to children as early as pre-school age and continue until the end of high school. The topics to be covered depend on the age of the children and is important that the content be age appropriate. For example, younger children can be taught to hold their parents' hands when crossing the road, older children can be taught to wear a bicycle helmet, and teenagers can be taught about the risks of speeding and drunk driving. Starting road safety education at an early age implies appropriate attitudes, first as pedestrians and cyclists, and then as drivers.

The evaluation of a school's road safety education program (like any other road safety program) is important to determine whether it is having a positive effect on students and whether it can be improved.

The evaluation of crash casualty reduction can be difficult and expensive, since very large samples are required. This is the reason why education programs are sometimes evaluated in terms of behavior changes and improvement of knowledge and attitudes on safer road use.

Advertising and education should also be combined with the enforcement of laws and the use of sanctions. The rules of the road are only likely to be observed if there is awareness that disregarding them leads to undesirable consequences such as fines or cancellation of the driver's license.

Enforcement can influence the behavior of road users through two processes:

- General deterrence: It occurs when road users comply with traffic rules due to the perceived risk of being caught or punished.
- Specific deterrence: It occurs when those who have already broken the rules and received the corresponding penalties are deterred from committing future offending actions.

Traffic enforcement should be aimed first and foremost at creating a general deterrent effect. This way, it is no longer necessary for the police to catch and punish violators to encourage them to obey the rules. To achieve a general deterrent effect, enforcement should be unpredictable, difficult to avoid, and adequately funded.

To maximize road safety benefits, enforcement should be targeted at traffic violations that have been shown to increase the likelihood or severity of road crashes. These benefits can be further enhanced through intelligence-led policing. In road safety enforcement, it involves the use of data (e.g., data on when and where crashes occur, data on severity factors such as non-use of seat belts or helmets, or data on causal factors such as speeding or drunk driving) to focus enforcement during specific time periods or in locations of greatest risk.

Box 13: Example of Global Training Initiative to Build Sustainable Communities

The United Nations Institute for Training and Research proposes a global training initiative, according to which road safety is essential to build sustainable cities and communities.

This initiative has set three targets to be reached by 2030:

Target	Actions
The percentage of motor vehicles occupants using restraint systems must be increased to 100%	• Promote the correct use of restraint systems (e.g., seat belts) by government officials. • Encourage the use of child restraint systems by parents and grandparents. • Promote road safety campaigns through media
The number of crash casualties due to alcohol consumption should be cut in half; likewise, the number of casualties due to the use of other psychoactive substances should be reduced	• Enable police officers to effectively enforce the law and to implement campaigns to change the behaviors of road users not compatible with the law
The provision of first aid must take place shortly after the road crash has occurred.	• Enhance the skills of first responders, such as emergency care, and rescue techniques applied to children at the scene of a crash.

Source: United Nations Institute for Training and Research

APPENDIX 1

Sample Data Forms

Police Form

General crash information (maximum one form per crash)

Police Department/Unit			
Officer name			
Report date			
Telephone number			
Crash variable	**Answer format**	**Crash variable**	**Answer format**
Crash ID	Ten-digit code (country Alpha-2 code, date in the format YYYYMMDD and 4 increasing digits starting from 0000).	**Date**	Selectable from calendar (DD/MM/YYYY)
Time	Selectable from clock (hh:mm)	**Region**	Multiple choice answer preferred
City/Location	Open text	**GPS coordinates**	Possibly entered automatically by GPS system
Crash or impact type	Multiple choice answer	**Weather conditions**	Multiple choice answer
Light conditions	Multiple choice answer	**Crash severity**	Multiple choice answer

Road-related variables (maximum one form per crash)

Crash variable	Answer format	Crash variable	Answer format
Road	Open text	**Functional class – 1st road**	Multiple choice answer
Functional class – 2nd road (if intersection)	Multiple choice answer	**Carriageway type**	Multiple choice answer
Number of lanes	Two-digit code	**Surface conditions and status**	Multiple choice answer
Street lighting	Multiple choice answer	**Speed limit**	Two- or three-digit code
Road type	Multiple choice answer	**Type of intersection**	Multiple choice answer
Type of intersection control	Multiple choice answer	**Work zone**	Multiple choice answer
Urban area	Multiple choice answer		

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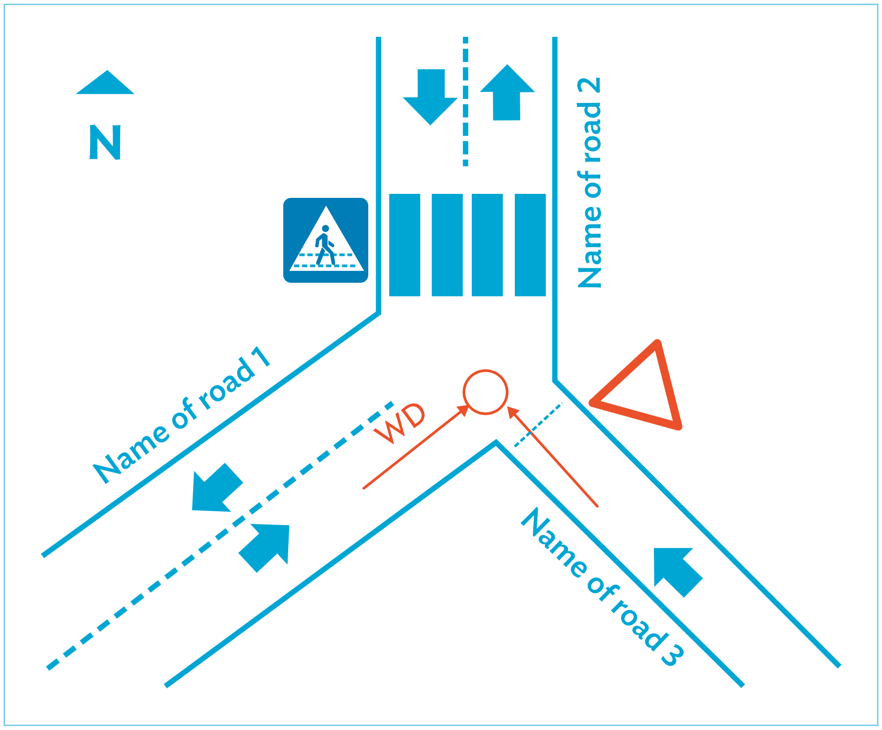
Traffic-unit-related variables (one separate form for each traffic unit involved in the crash)

Crash variable	Answer format	Crash variable	Answer format
Traffic unit ID	Two-digit code	**Traffic unit type**	Multiple choice answer
Trailer	Multiple choice answer	**Vehicle registration year**	Four-digit code (YYYY)
Vehicle registration country	Selectable from preset list of countries	**Traffic unit maneuver**	Multiple choice answer
Insurance	Multiple choice answer	**Technical inspection**	Multiple choice answer
Overloading	Multiple choice answer	**Hit and Run**	Multiple choice answer

Person-related variables (one separate form for each person involved in the crash; each person form is associated to the respective traffic unit form)

Crash variable	Answer format	Crash variable	Answer format
Person ID	Two-digit code	**Name and surname**	Open text
Date of birth	Selectable from calendar (DD/MM/YYYY)	**Gender**	Multiple choice answer
Nationality	Selectable from preset list of countries	**Road user type**	Multiple choice answer
Seating position in/on vehicle	Multiple choice answer	**Driving license issue date**	Selectable from calendar (MM/YYYY)
Driving license validity	Multiple choice answer	**Alcohol use**	Multiple choice answer
Safety equipment use	Multiple choice answer	**Distracted by electronic device**	Multiple choice answer

Example of collision diagram (developed using software or by hand at the scene of the crash—as preferred—or upon returning to the office)



Health Sector/Hospital Form

Crash variable	Answer format	Crash variable	Answer format
Crash-related variables			
Crash ID	10-digit code (country Alpha-2 code, date in the format YYYYMMDD and 4 increasing digits starting from 0000).	**Date**	Selectable from calendar (DD/MM/YYYY)
Time	Selectable from clock (hh:mm)		
Person-related variables			
Person ID	Two-digit code	**Name and surname**	Open text
Date of birth	Selectable from calendar (DD/MM/YYYY)	**Gender**	Multiple choice answer
Date of admission	Selectable from calendar (DD/MM/YYYY)	**Time of admission**	Selectable from clock (hh:mm)
Date of exit	Selectable from calendar (DD/MM/YYYY)	**Injury severity**	Multiple choice answer
Type of injury	Multiple choice answer		

Standard Definitions for Crash Variables

Table A1.1: Crash or Impact Type

No.	Definition
01	**Not applicable** Crash not describable by this variable.
02	**Crash with pedestrian crossing the road** Crash with a pedestrian crossing the carriageway (regardless of the presence of pedestrian crossing facilities).
03	**Crash with pedestrian walking or standing on the road side** Crash with a pedestrian standing or walking outside the carriageway (e.g., on a sidewalk, bicycle facility, or roadside strip).
04	**Other pedestrian crash** Collision with a pedestrian other than the options above.
05	**Crash with cyclist** Collision with a bicycle or two- or three-wheeled light nonmotorized/electric/or low-powered vehicle.
06	**Collision with parked vehicle** Collision with a parked vehicle (regardless of whether it is parked on the right or left side of the carriageway, or whether it was caused by opening the door or other factors).
07	**Single-vehicle crash** Crash not involving other vehicles or pedestrians. This includes crashes with animals, fixed obstacles, roadwork materials, trains, or non-fixed obstacles. It also includes single-vehicle run-offs in embankments or open fields without impact.

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Table A1.1 continued

No.	Definition
08	**Crashes between vehicles: overtaking** Collision between at least two vehicles in which one of them was performing an overtaking maneuver that was significant to the crash.
09	**Crashes between vehicles: rear-end collision** Rear-end collision between two or more vehicles.
10	**Crashes between vehicles: side collision** Side collision between two or more vehicles (either proceeding in the same direction or in opposite directions).
11	**Crashes between vehicles: head-on collision** Head-on collision between at least two vehicles proceeding in opposite directions.
12	**Crashes between vehicles: turning or crossing** Collision between two or more vehicles, one of which made a turning or crossing maneuver just before the crash.
13	**Crashes between vehicles: other** Crashes other than those listed above involving at least two vehicles.
99	**Unknown**

Table A1.2: Type of Intersection

No.	Definition
01	**Not at junction** Crash did not occur at or near (within 20 meters) a junction.
02	**At-grade: multiple-leg intersection** Road intersection with more than four arms.
03	**At-grade: four-leg intersection** Road intersection with four arms.
04	**At-grade: three-leg intersection** Road intersection with three arms.
05	**Roundabout** Circular road and last 20 meters of the approach sections.
06	**Grade-separated intersection** Interchange between roads crossing at different levels. Merge and exit lanes are included.
07	**Unspecified junction** The crash occurred at or within 20 meters of an intersection, but the type of intersection is unclear or different from the previous options.
99	**Unknown**

Table A1.3: Type of Intersection Control

No.	Definition
01	**Not at intersection** Crash did not occur at or near (within 20 m) an intersection.
02	**Authorized person** Police officer or was controlling traffic at intersection at the time of the crash.
03	**Static signs (give way or stop signs and/or marking)** Priorities at intersections are controlled by give way signage and/or stop signage.
04	**Traffic signal** Priorities are defined by an automatic traffic signal.
05	**Uncontrolled** The junction is not controlled by an authorized person, signs, markings, traffic signals or other devices.
99	**Unknown**

Table A1.4: Traffic Unit Type

No.	Definition
01	**Pedal cycle** Non-motorized two-, three- or four-wheeled vehicle. In some cases, it can also include electric and low-powered light vehicles.
02	**Motorcycle** Two- or three-wheeled vehicle that features an internal combustion system.
03	**Other three-wheeler or four-wheeled light vehicles** Quads, rickshaws, or other types of light motorized vehicles that cannot be classified as motorcycles or cars.
04	**Car** Motor vehicle with four wheels, mainly used to transport people, with no more than eight seats. It includes both cars for private or public transport (taxi). Four- or six-wheeled pickups also fall into this category.
05	**Minibus** Privately operated mini- and midbuses: passenger vehicle with between nine and 16 seats. Those vehicles that have these characteristics and are used as cabs fall into this category.
06	**Bus** Public transport vehicles that have more than 16 seats.
07	**Trolley/tram** Electric-powered public transport vehicles that have more than 16 seats.
08	**Goods vehicle under 3.5 tons (t) maximum gross weight (mgw)** Vehicle weighing less than 3.5t used for the transportation of goods.
09	**Goods vehicle over 3.5t mgw** Vehicle weighing more than 3.5t used for the transportation of goods.
10	**Road tractor** Vehicle used to transport non-motor vehicles (mainly semi-trailers).

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Table A1.4 continued

No.	Definition
11	**Farm tractor** Vehicle used for agricultural purposes.
12	**Ridden animal** Animal with human rider. Includes animal-drawn vehicles.
13	**Other vehicle** Other vehicle not included in the options listed above.
14	**Pedestrian** Person on foot; person pushing or holding bicycle; person who uses a wheelchair/pram/pushchair; leading or herding an animal; riding a toy cycle on the footway; person on roller skates, skateboard or skis. Does not include persons in the act of boarding or alighting from a vehicle.
99	**Unknown**

Table A1.5: Traffic Unit Maneuver

No.	Definition
99	**Unknown**
100	**Vehicle maneuver**
101	**Not applicable** Stationary vehicle (at a red light, at a stop sign, parked, etc.).
102	**Reversing** The vehicle was reversing.
103	**Entry or exit from a parking lot** The vehicle was entering or exiting from a parking lot. It does not include parked and stationary vehicles.
104	**Slowing or stopping** The vehicle was slowing or stopping.
105	**Starting to move** The vehicle started to move. It does not include vehicles entering or leaving a parking position.
106	**U-turn** The vehicle was performing a U-turn.
107	**Turning left** The vehicle was turning left.
108	**Turning right** The vehicle was waiting to make a right or a left turn.
109	**Waiting to turn** The vehicle was waiting to turn left or right.
110	**Changing lane** The vehicle was changing lane.
111	**Overtaking on the left** The vehicle was performing an overtaking maneuver on the left.

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Table A1.5 continued

No.	Definition
112	**Overtaking on the right** The vehicle was performing an overtaking maneuver on the right.
113	**Drifting out of its lane** The vehicle was leaving its lane of travel (either in its own direction or in the opposite direction).
114	**Other** Vehicle maneuvering other than those listed above.
200	**Pedestrian maneuver**
201	**Not applicable** Traffic unit is not related to pedestrians.
202	**Use of a crosswalk to cross the road** The pedestrian was using a crosswalk to cross the road. All types of at-grade, raised, or grade-separated facilities are included.
203	**Crossing outside a crosswalk** The pedestrian was crossing the road, but not on a crosswalk.
204	**Walking or standing on the carriageway** The pedestrian was walking or standing on the carriageway.
205	**Walking or standing outside the carriageway** The pedestrian was walking or standing outside the carriageway (on a sidewalk, roadside space, etc.).
206	**Entering or exiting a vehicle** The pedestrian was getting into or out of a vehicle.
207	**Other** Pedestrian movement other than those listed above.

Table A1.6: Type of Injury

No.	Definition
01	**Head injury** The person has suffered a head injury.
02	**Limb fracture** The person has suffered a fracture in one or more limbs (legs or arms).
04	**Multiple fracture** The person has suffered a multiple fracture in one or more limbs (legs or arms) and other parts of the body.
05	**Injury to the spine** The person has contracted an injury to the spine.
06	**Minor injury other than previous** The person suffered a minor injury other than those listed above.
07	**Serious injury other than previous** The person suffered a serious injury other than those listed above.
99	**Unknown**

APPENDIX 2
Possible Crash Contributing Factors

This appendix provides examples of the possible crash contributing factors, according to different crash types and/or patterns. The list does not intend to be exhaustive; several other contributing factors should be taken into consideration for the crash investigation procedures.

Table A2.1: Possible Factors Contributing to Road Crashes That Involve Pedestrians and Cyclists

Type of Road Crash/Pattern	Possible Contributory Factor
Motorized vehicle-bicyclist	Low visual distance
	Inappropriate signage
	Inappropriate road markings
	Inappropriate street lighting
	Excessive speed
	Presence of bicycles on the roadway
	Bicycle path located adjacent to the roadway
	Narrow bicycle paths
Motorized vehicle-pedestrian	Low visual distance
	Inappropriate safety barriers between pedestrian and vehicles
	Inappropriate signage
	Inappropriate signal phase shifting
	Inappropriate road markings
	Inappropriate street lighting
	Inappropriate mid-block crossings signage
	Lack of possibility of crossing
	Overspeed
	Presence of pedestrians on the roadway
	High distance to the nearest crosswalk
	Sidewalk too close to the roadway
	School-crossing area

Source: American Association of State Highway Transportation Officials (AASHTO), 2010.

Table A2.2: Possible Factors Contributing to Road Crashes Along Road Segments

Type of Road Crash/Pattern	Possible Contributory Factor
Rollover of the vehicle	Design of the roadside (e.g., untraversable side slopes)
	Inadequate width of the shoulders
	Overspeed
	Road paving design
Fixed element	Obstacle placed on or adjacent to the roadway
	Inappropriate street lighting
	Inappropriate road markings
	Inadequate signage and safety barriers
	Slippery surface
	Design of the roadside (e.g., inappropriate clearance distance)
	Inappropriate geometry of the roadway
	Overspeed
Night period	Low visibility or lighting at night
	Low signage visibility
	Inappropriate channelling or delineation
	Overspeed
	Low visual distance
Wet surface	Road paving design (e.g., drainage elements, surface permeability)
	Inappropriate road markings
	Poor maintenance conditions
	Overspeed
Opposite direction Traverse or frontal	Inappropriate geometry of the roadway
	Inappropriate shoulders
	Overspeed
	Inappropriate road markings
	Inappropriate signage
Run off the road	Inadequate width of the lane
	Slippery surface
	Inadequate width of the median
	Poor maintenance conditions
	Inappropriate shoulders
	Low visibility
	Overspeed
Bridge	Horizontal/vertical alignment
	Restricted width of the roadway
	Visibility conditions
	Vertical clear space
	Slippery surface
	Rough surface
	Inappropriate safety barriers

Source: AASHTO, 2010.

Table A2.3: Possible Factors Contributing to Road Crashes at Signalized Intersections

Type of Road Crash/Pattern	Possible Contributory Factor
Right-angle	Low signage visibility
	Inadequate timing of signals
	Overspeed
	Slippery surface
	Inadequate visual distance
	Drivers passing through red lights
Rear-end or Sideswipe	Inadequate speed of approach
	Low signage visibility
	Unexpected lane changes on approach
	Limited width of the lanes
	Unexpected arrests on approach
	Slippery surface
	Overspeed
Left- or right-turn movement	Incorrect evaluation of incoming traffic speed
	Conflicts between pedestrians and/or cyclists
	Inadequate timing of signals
	Low visual distance
	Conflict with vehicles turning right on red light
Night period	Low visibility or lighting at night
	Low visibility of signs
	Inappropriate channelling or delineation
	Poor maintenance conditions
	Overspeed
	Low visual distance
Wet surface	Slippery surface
	Inappropriate road markings
	Poor maintenance conditions
	Overspeed

Source: AASHTO, 2010.

Table A2.4: Possible Factors Contributing to Road Crashes at Unsignalized Intersections

Type of Road Crash/Pattern4	Possible Contributory Factor
Angle	Low visual distance
	High volume of traffic
	High speed of approach
	Unexpected cross traffic
	Drivers who do not obey the “stop” sign
	Slippery surface
Rear-end	Pedestrian crosswalk
	Inattention of the driver
	Slippery surface
	High number of turning vehicles
	Unexpected change of lanes
	Limited width of the lanes
	Limited visual distance
	Inadequate traffic gaps
	Overspeed
Collisions at driveways	Vehicles turning to the left
	Incorrectly placed driveway
	Vehicles turning to the right
	High volume of crossing traffic
	High volume of driveway traffic
	Low visual distance
	Overspeed
Head-on or sideswipe	Inappropriate road markings
	Limited width of the lanes
Left- or right-turn	Inadequate traffic gaps
	Limited visual distance
Nighttime	Low visibility or lighting at night
	Low signage visibility
	Inappropriate channelling or delineation
	Overspeed
	Low visual distance
Wet pavement	Slippery surface
	Inappropriate road markings
	Poor maintenance conditions
	Overspeed

Source: AASHTO, 2010.

CAREC Road Crash Investigation Manual

This manual sets out ways to improve procedures for collecting, investigating, and analyzing road crash data in the 11 Central Asia Regional Economic Cooperation (CAREC) Program countries to support informed decision-making and boost road safety. Analyzing the impact of fatal and serious road crashes which cost countries up to 5% of gross domestic product and dent development, the manual makes recommendations based on globally recognized best practices. Stressing the need for clear accident reporting and the maintenance of road safety databases, it shows how reliable data can support road safety education and advertising campaigns, strengthen traffic enforcement, and reduce crash casualties.

About the Central Asia Regional Economic Cooperation Program

The Central Asia Regional Economic Cooperation (CAREC) Program is a partnership of 11 member countries and development partners working together to promote development through cooperation, leading to accelerated economic growth and poverty reduction. It is guided by the overarching vision of "Good Neighbors, Good Partners, and Good Prospects." CAREC countries include Afghanistan, Azerbaijan, the People's Republic of China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan.

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